University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET

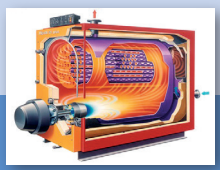
UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

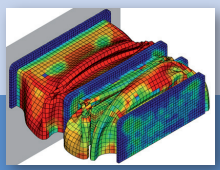
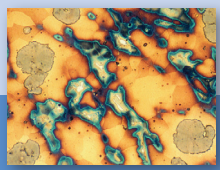
Seventh Annual PhD Workshop

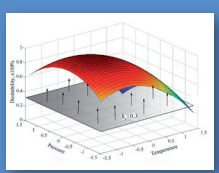
PhD Study of Mechanical Engineering, Naval Architecture,
Aeronautical Engineering and Metallurgical Engineering

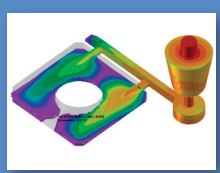
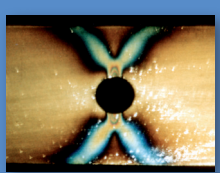
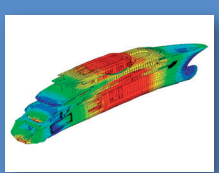
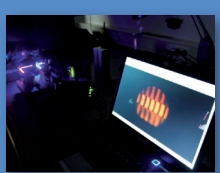
Book of Abstracts

July 5, 2021



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Preface

This booklet contains abstracts presented at the 7th Annual PhD Workshop, which took place on July 5, 2021. 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.

42 participants on the PhD workshop presented preliminary topics of their theses, while 15 participants presented final PhD topics. 55 workshop participants are from Croatia, while 2 are from foreign countries (1 from Cyprus and 1 from Colombia). Contributions collected in the booklet of abstracts are from different modules of the PhD study: Process and Energy Engineering (11 contributions), Computational Mechanics (9), Theory of Structures (7), Mechatronics and Robotics (4), Industrial Engineering and Management (3), Scientific Metrology in Mechanical Engineering (4), Aeronautical Engineering (3), Materials Engineering (8), Advanced Production Technologies (3), Naval Architecture and Ocean Engineering (4) and Metallurgical Engineering (1). 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

Comparison Between Two Types of Screw Configuration Methods in Treating of Pauwels Type III Femoral Neck Fracture: A Finite Element Analysis

PhD candidate: Petra Adamović
Mentor/s: Janoš Kodvanj, Srećko Sabalić
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Introduction

Intracapsular hip fractures in the young patients are typically a high energy injury fractures which are commonly known as Pauwels type III. Artificial head replacement surgery is usually not considered for treating femoral neck fractures in such patients. The commonly used devices for fixation of vertical femoral neck fractures are multiple screws or a sliding hip screw with or without an anti-rotation screw. Size, location, and length of the screws are the most effective parameters in terms of structural performance of internal fixation implants, but the optimal configuration of the screws is necessary to be investigated to guide the clinical practice.

Aims

The aim of this study is to compare the biomechanical stability of two screw configurations one of which is an inverted triangle and the other one is an "x-crossed" assembly.

Methods

A left femur bone model was obtained using a computer tomography scan. Geometry of the bone and bone-screw assemblies were formed using a combination of 3D software. A finite element analysis was carried out for the inverted triangle assembly and "x-crossed" assembly. In the latter, the first screw was positioned close to the inferior cortex of the femoral neck along the axis of the femoral head and the other two screws were positioned close to the anterior and posterior cortex in an "x-cross" shape.

Expected scientific contribution

Finite element analysis showed that the "x-cross" screw configuration withstands higher von Mises stress while maintaining less shear displacement on the fracture in regard to the inverted triangle configuration which withstands smaller von Mises stress and greater shear fracture displacement. The "x-crossed" screw configuration provides better performance than the inverted triangle configuration in terms of biomechanical stability.

Keywords

finite element analysis, biomechanical stability, inverted triangle, femoral neck fracture, Pauwels Type III

Experimental Determination of Vapour Pressure of Mineral Oil

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Introduction

The knowledge of the exact experimental vapor pressures or of an equation for calculating the vapor pressures function of the absolute temperature is important. Numerous empirical vapor-pressure equations have been published. Many of the relations are developed by integrating the Clapeyron equation and assuming that the behavior of the enthalpy of vaporization over the volume change of vaporization is a function of temperature or pressure.

The main purpose of determination the vapor pressure of mineral oil is to obtain its influence on absolute pressure in closed container of basic calibration system which is used for calibrating gas flow working standards in the laboratory for testing and verifying gas flow meters in Zagreb gasworks. The basic calibration system in the nominal measurement range from 0,4 m^3/h up to 2 m^3/h. In this system the absolute pressure is measured in closed container. The closed container is partially filled with oil. Since the oil is volatile the partial pressure of evaporated oil is generated in the container. The partial pressure of evaporated oil is determined according to Dalton's law.

The main principle of determination of the vapor pressure of oil is as follows. A container, a syringe filled with oil with known density is placed on the balance. After determination the mass of container filled with oil it is replaced from balance and it is filled with air from surroundings by syringe with needle. The air which flows into container replaces the same volume of oil which is put out and collected in an open container. By this the volume of air is determined by weighing of oil put out from closed container. Since the oil density is known the volume of oil in the open tank could be obtained by weighing. Although the described principle is simple, corrections of buoyancy force during weighing and corrections of temperature gradients in oil and air in the system need to be made

Aims

The main purpose of determination the vapor pressure of mineral oil is to obtain its influence on absolute pressure in closed container of basic calibration system which is used for calibrating gas flow working standards in the laboratory for testing and verifying gas flow meters in Zagreb gasworks.

Methods

The description of measurement process is based on equation of state for real gases. The vapor pressure of oil is based on Dalton's law. The compressibility of moist air, is calculated according to R. S. Davis.

Acknowledgments

The experiments show that the vapor pressure of investigated mineral oil is function of temperature where vapor pressure rises with temperature of oil for range given. The obtained vapor pressure stretches from 22,35 Pa up to 22,70 Pa in range from 15 °C up to 35 °C with characteristic which could be described by appropriate approximation. The results of measurements show that the absolute pressure in the gas flow measurement systems where vapor pressure is present can be corrected for amount of magnitude of order of 22 Pa or approximately 0,02 % at pressures near atmospheric. The results of measurements can be used for improving the basic calibration system for gas flow measurement in Zagreb Gasworks.

Keywords

vapor pressure, weighing method, gas flow measurement, measurement uncertainty

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

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Introduction

Considering that weldability of P91 steel is relatively constrained and requires precises heat input mechanisms with post weld heat treatment, this work will analyse the influence of alternating current parameters at TIG welding on weld joint properties. Since the frequency of alternating current and the waveform balance can change the heat distribution between the electrode and the workpiece depending on current values, it is consequently possible to form a weld joint of a certain geometry and microstructure.

Aims

The aim of this work is to investigate the application of alternating current in TIG welding of P91 steel and to quantify the influence of frequency and polarity balance on welded joint properties and residual stresses. With the specific waveform and parameters of alternating current (frequency, polarity balance) it is possible to influence the microstructure, geometry and mechanical properties of the welded joint. The alternating current parameters cause a change in the intensity of residual stresses in the welded joint.

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. The hardness test of the welded joints will be performed by the Vickers method HV10 in accordance with the applicable standard HRN EN ISO 15614-1 and specifications for welded joints, in the areas of base material, heat affected zone and weld metal. The mechanical properties of the welded joint will be performed by a static tensile test which will obtain tensile strength values (requirement min Rm = 585 MPa). 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. Microstructure analysis will determine how the AC TIG welding process affects the change in the microstructure of the weld joints with emphasis on the heat affected zone, in relation to conventional used welding processes. Due to mostly harmful effects of residual stresses on welded joints of martensitic steel P91 which are manifested through the potential formation and propagation cracks and other imperfections that may occur in welded joints, reducing the service life and integrity of the welded structures, 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 using RSM-Response Surface Method.

Expected scientific contribution

Defining optimal energy inputs for TIG welding of P91 steel by alternating current. Model of specific parameters influence of alternating current (polarity balance, frequency) on the properties of welded steel joint P91 and residual stresses.

Keywords

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

Development of a Simulation Model to Determine the Key Performance Indicators of Shipyard's Processing Lines

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Introduction

Shipyard's processing lines are the backbone of every ship production process. All structure elements for the hull and superstructure are produced by such machines. The whole production chain depends on these processing lines. Therefore, it is of high importance to define and design their key performance indicators.

There are various approaches to design such lines, the first one is the analytical approach, the second approach is the semi-analytical, and finally the numerical approach. The common goal of all approaches is to determine the key performance indicators: production rate, PR, work in process, WIP_i, blockade, BL_i, starvation, ST_i, and thruput.

The production rate defines the expected number of pieces per cycle time produced by the last machine. The work in process is the average number of semi-products at the i^{th} buffer. The blockade defines the probability that the i^{th} machine is not working because the subsequent buffer is full. The parameter starvation defines the probability that the i^{th} machine can not work since the preceding buffer is empty. The thruput is the number of products which the line produce in a specific period.

The analytical approach was recently extended for lines with arbitrary numbers of machines and buffers. However, it is not a useful tool for everyday practice because of the high computing demand. The semi-analytical approach can be divided into the aggregation method, decomposition method, and the recently developed finite-state method which is capable to calculate the steady-state probability distribution for the whole line. Finally, the numerical approach is the most common way to design production lines, however, it requires a lot of preparation time and skills.

Aims

The main goal of this doctoral thesis is to develop a simulation model to determine the key performance indicators of shipyard's processing lines. Further bottleneck detection tools will be developed based on the analytical definition for the production rate, the work in process, the probability of blockade, and the probability of starvation.

Methods

The simulation model for the shipyard's processing lines will be programmed in Fortran using the finite state method and a splitting line approach. Key performance indicators for the prefabrication and the fabrication of plates and profiles will be generated. The model will be validated by the analytical approach, the numerical approach, and by data from the real production. For the numerical approach, Microsoft dynamics will be used. The real production data will be acquired by in-site measurement in a shipyard.

Expected scientific contribution

The main scientific contribution will be a simulation model to determine the key performance indicators of a shipyard`s processing line. Further contribution will be the implementation of these performance indicators into the process of ship design to enable more fact-based definition of the terms of contract like deadlines and costs.

Acknowledgments

The research is supported by the Croatian Science Foundation, project UIP-2019-04-6573 ANTYARD (Advanced Methodologies for Cost Effective, Energy Efficient and Environmentally Friendly Ship Production Process Design).

Keywords

Ship production process, processing lines, key performance indicators, finite state method

N/TiO_2 Nanoparticles: Microwave-Assisted Synthesis, Characterisation, and Photocatalytic Activity Under Different Radiation Sources

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Introduction

Nowadays, the so-called organic micropollutants (OMPs) that are mainly pharmaceuticals, personal care products, pesticides, etc., are an important concern because they are harmful to aquatic life and usually are not removed by conventional wastewater treatment plants. That is why additional processes that can efficiently remove these OMPs are required. TiO_2 heterogeneous photocatalysis, which is one of the advanced oxidation processes (AOPs), has been considered as an excellent alternative for the removal of OMPs due to its capacity to produce strong oxidisers when it is irradiated by light. However, photoactivation of TiO_2 occurs only under UV light and the photogenerated charges that start oxidation processes recombine quite fast, affecting the photocatalytic activity. Nitrogen doping of TiO_2 has demonstrated a promising approach for shifting the optical response of TiO_2 to the visible light range. Therefore, this study focuses on the synthesis of N/TiO_2 photocatalyst using the non-conventional microwave-assisted method, evaluating the amount of nitrogen on photocatalytic activity for the degradation of ciprofloxacin in water using different sources of radiation.

Aims

This study aims to synthesise photocatalysts based on nanostructured nitrogen-doped TiO_2 using the microwave-assisted method to produce a material with low bandgap energy and increase visible-light-driven photocatalytic activity, which could use solar energy efficiently for the removal or degradation of OMPs from water.

Methods

N/TiO_2 nanocomposites will be synthesised using urea as a source of nitrogen. In order to evaluate the effect of nitrogen in the photocatalytic and morphological properties, N/TiO_2 will be prepared changing the amount of urea (0 – 10 g of urea). For this synthesis, urea will be dissolved in deionised water and mixed with stable TiO_2 sol. The obtained solution will be heated in the microwave oven at a defined temperature and reaction time. The synthesised photocatalysts will be characterised by X-Ray Diffraction analysis, Raman and FTIR spectroscopies. The photocatalytic activity will be evaluated through the degradation of selected OMPs (e.g. ciprofloxacin) using UV-A radiation (365 nm), solar light simulator, and different visible lights (405 nm, cold visible radiation, warm visible radiation).

Expected scientific contribution

This research is expected to achieve development of N-doped TiO_2 photocatalyst and clarify how the amount of nitrogen modify the morphological properties (e.g. crystallinity, specific surface area, porosity, etc.) of the synthesised materials by the microwave-assisted method. Moreover, the influence of nitrogen on the photocatalytic activity for the degradation of OMPs will be quantified. Additionally, it is expected to understand how the nanocomposite photocatalytic performance is affected by the radiation sources of different radiation spectra.

Acknowledgments

This research is part of the NOWELTIES: Joint PhD Laboratory for New Materials and Inventive Water Treatment Technologies. Harnessing resources effectively through innovation. NOWELTIES Project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska Curie grant agreement No. 812880

Keywords

Microwave-assisted synthesis, N/TiO2, UV-Visible light photoactivity, organic micropollutants degradation.

Multi-Criteria Optimization of Inventory Management in Supply Chains Operating Under Stochastic Market Demand

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Introduction

Supply chains (SC) nowadays mostly operate in a global, highly complex environment. Due to increased customer awareness of environmental preservation and pressure from the legislation and competition, companies operating as part of modern SCs are additionally compelled to optimise their operations' economic and ecological performance. In this context, efficient inventory control and transportation, as key supply chain management processes, have a significant role. In order to optimise the performance of these processes within SCs, it is necessary to thoroughly analyse interdependencies of various influential variables and system constraints to gain relevant scientific and managerial insights from the organisational, economic and environmental aspect through precisely designed simulation experiments.

Aims

Analysis based on simulation modelling of SC operating under (R, s, S) inventory control policy will be conducted in this research, taking into an account wide range of influential real-world factors, such as stochastic demand, fill rate fulfilment, lead time and work time variations, together with various logistic and environmental parameters. The first objective is to determine behaviour and correlations of various SC performance factors related to (R, s, S) inventory control policy – average inventory levels, costs, number and size of inventory replenishments and greenhouse gas (GHG) emissions from delivery activities. As recent scientific literature recognises, operational adjustments and efficient inventory control can be effective tools for GHG emissions reduction. Identification of such possibilities related to inventory replenishment transportations is among this paper's objectives, aligning with European Union environmental policy targets for 2030 that require at least 40 % GHG emissions reduction compared to the 1990 levels. Thirdly, the aim is to identify whether a reduction of GHG emissions can be achieved through optimal inventory management in SCs without jeopardising the fulfilment of any of its operational segments.

Methods

Experimental research defined according to the relevant theoretical knowledge from the fields of industrial engineering and supply chain management will be performed. Numerical modelling and simulations, statistical description and analysis, and multi-criteria optimisation are methods that will be used.

Expected scientific contribution

There is an evident study gap on research that simultaneously analyse inventory, cost and environmental performances of SCs operating under (R, s, S) inventory control policy. This research aims to provide a valuable scientific contribution in that direction. The research should confirm a significant impact that operational decisions have on inventory, economic and environmental performance of SCs, and identify possibilities for the reduction of negative impacts. The research results will be published in international journals and presented at international scientific conferences.

Keywords

Multi-criteria optimization, supply chain management, inventory management, environmental impact, greenhouse gas emission

Markerless Patient Registration Based on Anatomical Parameters Optimized for Robotic Surgery

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Introduction

Robotics is gaining an increasing role in stereotactic neurosurgery. Most state of the art robotic systems use marker-based patient localization and registration while markerless localization is in its infancy.

One of the challenges of markerless localization and registration is face deformation. The human face can deform from the preoperative scanning phase to the operative position in the actual surgery. The face is not uniformly deformable which presents an opportunity for improving the markerless registration by using less deformable parts of the face while not registering more deformable parts.

Aims

The aim of this study is to improve markerless registration by taking the deformity of different face regions into account. The goal is to increase registration accuracy by using less deformable regions and excluding more deformable ones.

Methods

To enable accurate face registration, an algorithm for face registration needs to be developed. This algorithm needs to use weights for registration so that less deformable regions of the face can have a bigger impact on registration and vice versa. An algorithm for dividing the face surface into multiple regions will be developed, so that each region can have a different effect on registration, based on its deformation. The final step will be weights optimization using a genetic algorithm.

Expected scientific contribution

1. Method for estimating the weighted feature correspondences of anthropological deformable objects using optimization algorithms; with application to a human face, depending on the intensity and probabilities of deformations of individual anatomical regions.

2. Algorithm for the improved markerless registration of the human face based on the weighted feature correspondences of specific anatomical facial regions.

Keywords

markerless, registration, genetic algorithm

Multimodal Emotion Analysis Based on Acoustic and Linguistic Features of the Voice

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Introduction

Artificial speech analysis can be used to reveal non-verbal communication cues. Better understanding of speech can be achieved by analyzing the additional characteristics, like: tone, pitch, rate, intensity, meaning, etc. These characteristics can help to reveal the current emotional state of the person. Inability of appropriate recognition of emotions can inevitably lessens the quality of social interaction. Modern societies therefore strive to create software agents able to interact with people.

Aims

Nowadays the most of digital communication is placed on artificial environments like Internet in a form of audio or textual messages. Within real environments the software agent needs to acquire and digitalize the input for further processing. In this paper I presented a method for emotion recognition based on acoustic and linguistic features of the speech.

Methods

Defined aims are achieved by use of acoustic and linguistic modalities. Both modalities are based on neural networks trained on available open source databases. These sub-modalities are then fused together in a single voice modality trough an algorithm for multimodal information fusion. The overall system is tested at the end on recordings available through Internet services.

Acoustic sub-modality is relying on a Convolutional Neural Network (CNN) architecture having eight dedicated layers. Network is trained on available open source databases: SAVEE, CREMA-D, RAVDESS, TESS and Emo-DB. Before the learning data is processed, two important features are extracted: (1) MFCC coefficients and (2) spectrogram. Both features are generated through the process of a time-to-frequency domain conversion based on FFT. Features are averaged for the whole audio recordings.

Linguistic sub-modality is achieved on a Long Short-Term Memory (LTSM) network architecture, containing four layers. The training data is acquired from the DailyDialog database. These statements are filtered through handcrafted algorithm, commonly known as bag-of-words. The whole sentences are then transferred into the number representation of words for optimized learning procedures.

The algorithm for multimodal information fusion contains the standard linear fusion function with equal factors. In another words, both results (acoustic and linguistic sub-modality outputs) are graded equally and combined to get the final decision. In this step, the emotion with the highest score is chosen as the most significant.

Expected scientific contribution

The main direction of this work is to provide an adaptive behavior of the system under uncertainties of the real world where deterministic chaos is a rule. When the created algorithm is implemented with interaction strategy, it will modify and improve beliefs of both sub-modalities. Also, interaction strategy would change weight factors depending on the beliefs of the whole system.

Acknowledgments

This work has been supported in part by Croatian Science Foundation under the project "Affective Multimodal Interaction based on Constructed Robot Cognition (UIP-2020-02-7184)".

Keywords

Emotion Recognition, Affective Robotics, Multi-modal Information Fusion, Voice Analysis, Speech Recognition

Influence of Heat Treatment of Aluminium Precursors on Energy Absorption of Aluminium Foams

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Introduction

Transport sector is responsible for 25 % of the greenhouse emissions in Europe, which is an ideal basis for improvement of standard cars. One of the ways to reduce emitted pollutants and fuel consumption is weight reduction of vehicles. There is a need for alternative materials in the industry to successfully replace or improve the current components while simultaneously the safety of the passenger cannot be compromised. Recently, researchers have shown an increased interest of production in the automotive industries. Material selection plays vital role to meet the functional requirements of components. Metal foams, including aluminium foams, have recently been attracting attention of the automotive industry. Their unique combination of properties, such as low density and good energy absorption characteristics, make them possibly an ideal material for making lighter vehicles, while simultaneously providing safety for passengers.

Aims

The aim is to investigate the influence of heat treatment of precursors on the early anisotropic expansion of precursors, as well as to determine the optimal parameters of the heat treatment process, in order to increase the value of specific energy absorption of aluminium foams and to investigate the effects of changing the position of precursors on foaming aluminium foams.

Methods

Two types of precursors were selected to produce aluminium foams by heating and gas releasing particles in a semi-solid state: AluLight AlMgSi0.6 + 0.4 % TiH_2 and AluLight AlSi10 + 0.8 % TiH_2. Before production, part of the precursors will be heat treated, wherein the heat treatment temperature and the holding time at that temperature will change, according to the design of experiments (DOE). During sample production, the position of the precursor within the mould will vary. The foaming time is different for each sample. The laboratory tests will involve a combination of destructive and non-destructive testing methods for aluminium foams. Since energy absorption is the subject of the research, the quasi-static uniaxial compression test was chosen for the destructive part of the testing. The characterization of aluminium foams will be performed, but the homogeneity of the samples themselves will also be analysed. Non-destructive methods are going to be used to have better understanding of the collapse mechanism of the cells and temperature change of specimens of aluminium foams. The Digital Image Correlation method will determine the field of displacement and distribution of deformations over the entire analysed area by comparing the image of the test sample at different stages of deformation. X-ray computed microtomography is a method that will show how homogeneous the material is, with eventual changes in microstructure, before being crushed.

Expected scientific contribution

The expected scientific contribution is developing methods for: 1) more reliable prediction of behaviour of aluminium foams under compression and 2) achieving more homogeneous microstructure of aluminium foams, regarding the heat treatment of precursors and their position inside the mould.

Keywords

Aluminium Foam, Specific Energy Absorption, Heat Treatment, Powder Metallurgy, Semi-Solid Expansion

Application of Computer Simulation for Vertical Centrifugal Casting of Stainless Steel

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Introduction

Today, the world is on the edge of a new industrial era based on the fast-evolving technology. As a response to technological changes in the metalworking industry and high customers requirements in the global market, vertical centrifugal castings are gaining application. Vertical centrifugal casting is a process of casting a liquid metal into a rotating mould cavity for obtaining the desired shape. The gating system of vertical centrifugal castings usually employs a single gate, which combines the function of gate and riser. When pouring the melt into the mould cavity, the axis of rotation of the mould is vertical. Vertical axis machines are also used for production of castings of asymmetrical configurations. Due to the high mould rotational speed, the casting is simultaneously affected by centrifugal and gravitational force where a centrifugal force is higher. Centrifugal force also produces a greater metal density in the casting than would otherwise result. Castings whose height is less than the diameter are the most often cast. It is used for casting short tubes, slide bearings and ring-shaped castings. Casting of stainless steel EN 1.4581 tube with an outer diameter of 84 mm, a height of 42 mm and the thickness of 7 mm, using the computer software was simulated. Centrifugal casting defects mainly relate to the solidification process, so the main aspect is understanding the solidification process in vertical centrifugal casting and identification of optimal parameters. Numerical simulation technology is widely utilized to simulate the temperature field, solidification, segregation, and microstructure evolution during the casting process, so casting has advanced from a non-visible to a visible process.

Aims

The aim of this experiment is to find optimal parameters and thus reduce the occurrence of defects. A significant problem of vertical centrifugal casting is related to the solidification process. With the help of numerical simulations, the flow of the molten metal can be easily predicted and it is clear how the solidification process takes place in the mould cavity.

Methods

The main parameters such as pouring rate, pouring temperature, mold preheating temperature and rotational speed of the mould were set. Effect of rotational speeds of 700 rpm, 1000 rpm and 1400 rpm at pouring temperature of 1485 °C was analysed and effect of pouring temperatures 1485 °C and 1510 °C at 1400 rpm was also analysed. For rotational speed of 1400 rpm and the pouring temperature of 1485 °C deformations, stresses and microstructure were simulated in ProCAST software, which is based on the finite element method. Also, simulation of filling and solidification was carried out using ProCAST software.

Expected scientific contribution

With this approach, the goal is to obtain casting which will be more economical because the possibility of defects is reduced. Also, a casting will have better surface quality, extended product life and better mechanical and tribological properties.

Acknowledgments

I would like to express my very great appreciation to company Fripol d.o.o. from Ljubešćica, Croatia.

Keywords

vertical centrifugal casting, casting parameters, numerical simulation, stainless steel, ProCAST software

An Overview of Measurement Methods of Residual Stresses in Welded Joints

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Introduction

Residual stress is a stress distribution that is present in a structure while there is no external load applied. The mechanisms of residual stress generation are not easily stopped, but they can be predicted. In welded structures, residual stresses are mainly the result of thermal expansion of the material. Materials tend to shrink as they cool, so welding residual stresses develop as the base material pulls back to maintain the bond with the shrinking weld metal. Depending on the type of welding parameters, component material and size, residual stress distribution varies.

Aims

Calculation of residual stresses in welds is very limited by measurement techniques, but of a high importance for fatigue material prediction.

Methods

Residual stress measurement methods can be classified into three types: nondestructive (X-ray, neutron diffraction, ultrasonic method and Barkhausen noise metod), semi destructive (hole drilling, ring-core and deep hole method) and destructive (sectionig compliance tecniques and contour metod). Given the production and inspection of the welded structures, it is also important to know and understand standards for nondestructive measurement techniques.

Expected scientific contribution

Through the content of the paper, non-destructive methods of testing residual stresses in welds will be described in detail. For every method will be listed physical limitations, scope of the method and advatages and disadvantages. This paper will classify residual stress measurement methods and provide information for further research in the field.

Keywords

welding, residual stress, measurement method

Numerical Modeling and Optimization of Structures Under Blast Impact

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Introduction

Making a blast impact resistant construction is a complex and expensive process. Various types of materials and their combinations are used for blast armor: metals, polymers, glass, ceramics, and fabric. A reliable numerical model for verifying different material and shape combinations would greatly reduce the cost and development time. The subject of this research is the development of a numerical method for the optimization of the structure under blast impact. Constitutive model introduced in this work describes the behavior of structures exposed to blast impact. This model is basis for the optimization of structures under blast impact and selection the most favorable combination of shape and materials.

Aims

The main goal of this work is defining and implementation of a conductive model for describing the behavior of structures exposed to blast impact. This method will be applicable for different type's shapes and materials. The next step will be the developed process of validation and optimization for analyzed shapes and materials.

Methods

The research was conceived as a numerical analysis with the validation of a numerical model with the experiments. For this purpose, the commercial software Abaqus will be used at macro level, as a finite element method analysis tool. Programming of user subroutines will be performed in the Fortran77 programming language. Comparison and optimization algorithms will be developed in the Python programming language. The methods used in the numerical modeling of impacts and phenomena with high strain rates are divided into two groups. The first group includes improved constitutive models. The second one includes techniques used to avoid numerical problems due to physically unacceptable structural deformations. These problems are solved by applying the following techniques: Smooth Particle Hydrodynamics (SPH) and Coupled Eulerian-Lagrangian (CEL). The SPH approach is based on the meshless method, which eliminates the problem of element distortion. Continuum is discretized by particles, so it is not necessary to define the connections between the particles. For solving impact problem with high velocity (above 1300 m/s), where the material begins to behave more like a fluid, SPH shows good results. The CEL method combines features of Lagrangian and Eulerian analysis within the same mesh. The CEL method is used to control the distortion of elements in Lagrangian parts with large deformations, such as blast impact. Constitutive models used in these problems include models of plasticity and strain rate dependent damage model (Johnson-Cook model, Cowper-Symonds model).

Expected scientific contribution

The described method enables modeling of structures with different material combinations and shapes under blast impact. This method allows reliable predicting of the structure behavior and selection the most favorable materials and shapes.

Acknowledgments

This research is supported by the company DOK-ING d.o.o. from Zagreb, Croatia. I would like to thank DOK-ING d.o.o. for support in this investigation.

Keywords

blast, mine, numerical simulation, blast load, blast wave parameter

Improvement of Wave Statistics for the Prediction of Long-Term Responses of Marine Structures

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Introduction

Loads relevant for the design of marine structures include waves, wind, current, sea water level, and ice. Since sea waves usually represent dominant load type, wave prediction and associated uncertainties are crucial for the assessment of loads and responses of marine structures.

The wave environment is commonly described using a table containing probabilities of occurrence of sea states called wave scatter diagram. For fixed offshore structures, wave scatter diagrams are often available for specific locations, and the computation of the long-term distribution of wave loads or their extreme values, may be done by well-established engineering methods. For ships, however, the problem is more complicated because of their mobility and the unpredictable human actions.

The analysis of wave loads on ships assumes that short-term sea states that ship encounters during the voyage are statistically independent. This assumption is doubtful because of the correlation between successive sea states.

Aims

The objective of the thesis is to propose modifications of existing wave statistics aiming to improve the long-term response analysis of marine structures.

The main hypothesis of the proposed topic is that the spatial correlation between successive sea states along the ship sailing route can lead to the improvement and rationalization of those diagrams. Also, comparative analysis of wave data acquired from different sources will enable quantification of the uncertainty of long-term response prediction.

Methods

The effects of spatial correlation will be considered by assuming the sea states as members of a correlated series system. Wave scatter diagrams can be generated from different wave data sources. Hence, a comparative analysis will be performed upon the obtained results. The uncertainty analysis of the monthly and seasonal variability will be performed using data from available databases. The probability distribution of significant wave heights will be modeled by a 3-parameter Weibull distribution. The correlation coefficient will be calibrated based on the actual sea states along shipping routes in the North Atlantic and the Adriatic Sea, extracted from the ERA5 and OCEANOR database respectively. Finally, an uncertainty assessment will be performed, and the long-term analysis of ship response will be conducted using different previously generated wave descriptions. The seakeeping responses will be calculated using linear strip theory code PDSTRIP and closed-form expressions. Python will be used for calculations and data analysis.

Expected scientific contribution

New scatter diagrams for the analysis of ship structures accounting for spatial correlation among successive sea states. Quantification of the uncertainty in the long-term distributions of sea states and responses of marine structures caused by using wave data from different sources and considering monthly and seasonal variability of the wave climate.

Acknowledgments

This work has been partially supported by Croatian Science Foundation under the project IP-2019-04-2085. The ERA5 reanalysis data are available from the ECMWF. WorldWaves data – provided by Fugro OCEANOR AS. Python Software Foundation (https://www.python.org/).

Keywords

wave scatter diagram, spatial correlation, extreme wave loads, interannual wave climate variability, reliability-based design

Evaluation of Friction Between the Anti-Buckling Fixture and Thin Arcan Butterfly Samples Under Simple Shear Loading

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Introduction

The increasing exploitation conditions on the engineering components promote equally fast and adaptive manufacturing processes. This is apparent especially in the industry where metal forming is applied. The optimization and modelling of the forming process depends on Finite Element (FE) simulations where the defined material mechanical properties play a key role. For that purpose, mechanical tests need to be conducted to quantify the material behavior. However, the conventional uniaxial tensile tests do not provide comprehensive material information to predict the material response under complex workloads. Arcan fixture stands out as one of the most versatile fixture in terms of available loading possibilities, namely tensile, simple shear and the mixed-mode loading. The proposed rig employs butterfly samples with symmetric V notches in the gauge area to ensure uniform stress state between the notches. However, mechanical tests involving thin sheets subjected to simple shear often experience buckling which consequently prevents accurate characterization of the investigated material. The complex geometry of the butterfly samples demands the use of full-field measurement methods, from which Digital Image Correlation (DIC) stands out as the most widely used method. Such approach provides more detailed insight into the material behavior and localization phenomena.

Aims

The goal of the presented research was to disable the buckling of the thin butterfly samples subjected to simple shear loading on the modified Arcan fixture (MAF). To prevent folding of the sample, an anti-buckling fixture for the butterfly sample was developed. Furthermore, the influence of the anti-buckling setup on the displacement and strain fields was evaluated. Finally, friction between the sample and the additional fixture was assessed.

Methods

To prevent the sample buckling, the anti-buckling fixture, consisting of two transparent acrylic glass plates, was proposed. A monotonic simple shear test was carried out on the MAF with the proposed device. Furthermore, stereo optical system was employed to capture any out-of-plane motions. The displacement fields were measured via the FE stereoDIC algorithm which uses FE mesh of the sample geometry to obtain nodal displacements. The same FE model was then used for the identification procedure. The inverse Finite Element Model Updating (FEMU) algorithm was used to calibrate the plastic material parameters and the friction coefficient between the sample and acrylic plates by minimizing the displacement and force residuals (i.e., the difference between the calculated and measured quantities).

Expected scientific contribution

The upgraded experimental setup for testing thin sheets under simple shear loading with the MAF was proposed. The in-depth analysis of the displacement and strain fields revealed that the proposed anti-buckling fixture was sufficient to prevent sample buckling. Moreover, the advanced identification scheme revealed the influence of friction on the material parameters. Finally, the material parameters were calibrated along with the friction coefficient between the acrylic plates and the sample.

Acknowledgments

This research was performed within the FULL-INSPECT project supported by the Croatian Science Foundation (UIP-2019-04-5460 Grant).

Keywords

Arcan fixture, simple shear, inverse identification, FEMU, friction.

Hybrid Ozone-Ceramic Membrane Process: Increasing Hydroxyl Radical Yield and OMPs Reduction While Reducing Membrane Fouling

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Introduction

Organic micropollutants (OMPs) such as pharmaceuticals, antibiotics, personal care products, detergents, pesticides, etc., are chemicals that can be found in the wastewater streams at very low concentrations (μg/L or ng/L) and can cause deterioration of any aquatic system and consequently affecting human health when household and industrial wastewaters are poorly treated. Wastewater treatment, including physicochemical and biological processes, is crucial when it comes to water reuse i.e., converting wastewater into water that can be reused for other purposes. For example, before using the treated water for agricultural purposes it is required by law (Water Framework Directive 2000/60/EC) to meet a few standards so that it will neither pose harmful effects on the environment nor on human health. Conventional wastewater treatments are not able to eliminate these recalcitrant OMPs, therefore we need to establish efficient and sustainable technologies. Ozonation is a standard process applied for reducing OMPs' concentrations in secondary effluent. As many OMPs react slowly with ozone, an increased degree of conversion of ozone to hydroxyl radicals ($^{\bullet}OH$) is desirable, thus reducing the necessary transferred ozone dose.

Aims

The aim of this study is the development and implementation of a hybrid process consisting of ozonation and microfiltration filtration using ceramic membranes, for increasing micropollutant removal efficiency in the tertiary treatment of wastewater and, consequently improve wastewater quality before it is reused, recycled or discharged to the environment.

Methods

Four OMPs (amoxicillin, carbamazepine, ibuprofen, and diclofenac), including para-chlorobenzoic acid (pCBA) as $^{\bullet}OH$ probe and tetr-Butanol (t-BuOH) as a $^{\bullet}OH$ scavenger, will be used as model compounds. In preliminary experiments, different metal oxides (α-Al_2O_3, γ-Al_2O_3, Mn_2O_3, CeO_2, and TiO_2) will be used in batch experiments to test their catalytic activity towards heterogeneous ozonation, in the order to choose the most efficient metal oxide. The selected nanostructured metal oxide will be deposited on the surface of ceramic membranes by the sol-gel method. Experiments with the lab-scale unit hosting ozone and microfiltration will be performed. Modified membrane surfaces will be analyzed with different techniques (XRD, SEM, BET, FTIR, TEM, AFM, etc.) to understand how modified membranes work in the presence of ozone.

Expected scientific contribution

Heterogeneous catalytic ozonation has been widely studied, however, its combination with other treatment technologies, e.g., post-treatment filtration needs more investigation. It is expected that this research will assess the catalytic activity of the ozone using ceramic membranes as a substrate on treating wastewater secondary effluent. Additionally, it will evaluate the different pore sizes of a ceramic membrane and determine the impact on fouling, OMP degradation, and disinfection by-product (DBP) after pre-oxidation.

Acknowledgments

This research is supported by the NOWELTIES project "Joint PhD Laboratory for New Materials and Inventive Water Treatment Technologies. Harnessing resources effectively through innovation (Project ID: 812880), Call: H2020-MSCA-ITN-2018", that has received funding from the European Union's Horizon 2020 Research and Innovation program under the Marie Sklodowska-curie grant agreement.

Keywords

organic micropollutants, hybrid systems, catalytic ozonation, ceramic membranes, hydroxyl radicals

Development and Validation of a Surface Wear Model for Mixed Mode Lubricated Contact

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Introduction

The presence of wear is a well known reason for the failure of mechanical components in mechanical systems. Wear was rarely studied in detail using numerical analysis and was usually accounted for in the design stage of components by relying on complex and financially demanding experiments or engineering experience. With modern system design moving towards increased efficiency and optimisation, certain machine elements are expected to operate under conditions (e.g. mixed-mode lubrication or direct surface-to-surface contact) where understanding the wear phenomena becomes of significantly greater importance. Thus, a robust and accurate tool, which could be used to predict wear in such conditions, would be able to provide invaluable information on the effects of wear on lubricated contact pairs, their life expectancy and potential for optimisation.

Aims

The ultimate objective of the research presented here is the development of a numerical tool capable of predicting surface wear for contacts (contact pairs) under different loads and for different contact conditions (lubricated or unlubricated contact), while being sensitive to the surface roughness of real surfaces. The wear model needs to be able to predict surface wear, while being sensitive to measured real surface roughness data, load parameters and lubricant formulation. This research builds on the numerical lubrication model available in OpenFOAM, with the objective being the development and implementation of a surface wear model into the existing lubrication modelling framework. The starting point for the development of the surface wear model is the Archard Wear Equation, as it is widely used in the experimental and numerical investigation of wear. The wear model is to be expanded further to take into account contact surface interactions and existing micro-scale models based on the thermodynamics of friction and wear.

Methods

This research consists of a purely numerical investigation of the wear and lubrication phenomena, the implementation of the developed numerical models in the appropriate framework and validation of the results against experimental and numerical data available in the literature. The numerical framework used for the implementation of the newly developed models, which are based on the Finite Volume Method (FMV), will be implemented as part of foam-extend – a community driven fork of OpenFOAM, an open-source CFD (Computational Fluid Dynamics) numerical simulations library.

Expected scientific contribution

The expected scientific contribution of the presented research consists of the development, implementation and validation of a complex numerical surface wear model using the Finite Volume Framework. Once fully implemented and validated, the wear model should be able to take into account both dry and lubricated contact conditions and changes in the material properties of both the contacting surfaces and the lubricant.

Keywords

Lubrication, Wear, Contact Analysis, OpenFOAM

Influence of Solidification Rate on the Nodule Degeneration in Ductile Iron

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Introduction

Characteristic nodular form of graphite in ductile irons is achieved by inoculation and nodulation with magnesium and rare earth elements addition to the melt before or during pouring process. This contributes to the improvement of properties such as castability, strength and toughness of ductile iron. The properties of ductile iron are mainly influenced by alloying elements, casting technology, wall thickness and solidification rate which can affect the shape of graphite and metal matrix transformation. Graphite form in ductile irons is controlled by the growth through eutectic solidification till the eutectoid transformation temperature. Graphite nodule degeneration occurs in thick-walled castings due to the carbon diffusion on graphite nodules during slow cooling. In order to ensure required properties of ductile iron the focus of investigation will be on the mechanism of graphite growth, solidification and degeneration under different solidification conditions.

Aims

This research will focus on thick-walled castings characterized by higher ratio of irregular graphite nodules and lower mechanical properties. The input parameters will be chemical composition, melt treatment agents, pouring temperature and solidification time, while the output parameters represent microstructure and mechanical properties. The prevention of graphite nodule degeneration will contribute to the production of thick-walled castings with improvement of mechanical properties.

Methods

The experiment will include Y- and step tests CAD modeling and casting, selection and correction of the chemical composition, inoculants and nodulators. The experiment will be carried out by preparing the geometry in SolidWorks and selecting the appropriate parameters for numerical simulation of casting and solidification using ProCAST software support. Casting and solidification process in laboratory/industrial conditions will be monitored by thermal analysis, resulting with cooling curves. Afterwards the microstructure and mechanical properties investigation will be performed. Correlation of all acquired parameters and results will enable mathematical model setup for microstructure development and its indirect influence on obtained mechanical properties.

Expected scientific contribution

The comparison of simulations with casting and solidification process in laboratory/industrial conditions will enable determination of nodule degeneration mechanism during slow cooling. Development of mathematical model able to correlate significant parameters will help to predict the microstructure development and achievement of desired properties in the thick-walled casting.

Acknowledgments

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Keywords

ductile iron, graphite growth, solidification rate, wall thickness

Experimental Study of Electrochemical Hydrogen Compressor with Titan Foam

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Introduction

High-pressure hydrogen storage systems are indispensable for implementing hydrogen technology on a wider scale. Consequently, an efficient and carbon-neutral process of hydrogen compression is required, as, during production, hydrogen cannot reach adequately high pressures due to back diffusion [1]. An electrochemical hydrogen compressor (EHC) with an analogous working principle to proton exchange membrane (PEM) electrolyzer has turned out to be the most promising choice considering its noiseless operation, modularity, absence of moving part, and higher efficiency compared to conventional mechanical compressors [2]. In addition, multiple simultaneous operating benefits such as hydrogen purification and extraction of hydrogen from gaseous mixtures give electrochemical compression a further advantage [3].

Aims

According to existing research, EHCs are still not sufficiently developed and should, therefore, be further studied and properly upgraded to minimize the present limitations affecting the output pressure, such as membrane deformation under higher pressures, and hydrogen back diffusion to the anode [4]. In particular, improved design and more sufficient materials are necessary to increase efficiency. This research aims to experimentally determine whether higher hydrogen pressures can be achieved inside the EHC with the implementation of porous Titan (Ti) foam instead of metal bipolar plates with flow fields and Vulcan-carbon gas diffusion layers. Moreover, the experiment will represent a verification of a developed mathematical model with variable parameters that can be used for further research describing EHC.

Methods

Based on the analysis of the collected scientific papers, a new design solution with Ti foam is proposed. The scientific research will be conducted at the Power Engineering Laboratory at the Faculty of Mechanical Engineering and Naval Architecture including experimental approach and mathematical modelling. Equipment and materials for setting up the experimental path will be defined. When made, a laboratory EHC will be subjected to successive testing and a compatible mathematical model in MATLAB/Simulink Software will be developed. The results of the experimental measurements will be collected and processed, on which basis, the data obtained by mathematical modelling will be verified.

Expected scientific contribution

Given that an EHC containing Ti foam has not yet been constructed or studied, this experimental re-search will give a better insight into the impact of various physical parameters on its operation. Expected achievement of increased efficiency of the EHC, using a porous Ti foam instead of metal bipolar plates with flow fields and Vulcan-carbon gas diffusion layers will be experimentally verified and described with the adjacent mathematical model.

Keywords

Hydrogen, Electrochemical hydrogen compressor, Proton exchange membrane, Titan foam

Application of the Magnetic Field in Alkaline Water Electrolysis

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Introduction

Hydrogen technology is recognized as an essential part of the global energy transition towards a carbon-neutral society. However, it's ecological potential is still not fully utilized due to mainly economic reasons. One of the main problems is the current production cost of green hydrogen production compared to the cost of grey hydrogen. To reduce the costs and make the technology economically viable, production needs to scale up. One way to accelerate this process is by increasing the energy efficiency of green hydrogen production. The influence of the magnetic field on the water electrolysis was a topic of few types of research and all experimental results conclude positive effect, but results are not consistent.

Aims

The main aim of this research is to measure the amount of effect that magnetic field has on the process of water electrolysis. Previous research in this field indicates the positive influence of the magnetic field on the process of water electrolysis. However, there are several problems. The main problem is a small number of overall researches done in the field. As each research team, in general, uses different materials, type of electrolyzer, type of magnetic field or approach to the subject, there are major discrepancies in the results. Therefore, there is a need for additional research, since the previous result that varies among researchers, cannot be used for granted. To determine the impact and calculate the effect of the magnetic field on the process of water electrolysis, the experimental setup was designed.

Methods

The two main research method are experimental method and method of mathematical modelling. The experimental setup was designed in the Power Engineering Laboratory at the Faculty of Mechanical Engineering and Naval Architecture. The main part of the setup is a an electrolyzer powered by DC power supply. The type of electrolyzer is an alkaline with a 25 % potassium hydroxide (KOH) water solution as an electrolyte. The electrodes are made of nickel (Ni) plates and placed at a 25 mm distance from each other. The rest of the experimental equipment is consisting of additional measuring equipment for the measurement of temperature, pressure, the quantity of produced hydrogen, voltage, and electrical current. The application of the magnetic field on the electrolyzer is enabled by the usage of a couple of permanent neodymium magnets. Magnets are cubes with dimensions of edges of 25 mm. The north side of one magnet is facing the south side of the other magnet at the distance of 25 mm, enabling the body of the electrolyzer to fit in between. The experimental research will be conducted with the application of the magnetic field and without. Energy efficiencies for both types of processes will be calculated and compared, and the effect of the magnetic field on the process calculated.

Expected scientific contribution

The expected scientific contribution of this experimental research is a definitive and measurable calculation of the impact of the effect of the magnetic field on the water electrolysis that will ensure the credibility of the results and establish reliable methods for the future research.

Acknowledgments

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

Keywords

Hydrogen society, green hydrogen production, water electrolysis, alkaline electrolyzer, magnetic field

Dynamic Vehicle Routing Problems Solved by Ant Colony Optimization Algorithm

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Introduction

Vehicle Routing Problem (VRP) was first introduced in 1959, its goal is to construct an optimal solution, i.e. find routs with minimal cost, travel time, or environmental impact, for multiple vehicles that are visiting n number of nodes (also called locations or customers). VRP is considered a static problem as all information is known before route planning. In contrast with VRP, in the Dynamic Vehicle Routing Problem (DVRP) all relevant information is not known before the planning process begins, and information can change after initial routes have been planned. DVRP was first introduced in 1980 and since then it has been a topic of scientific interest, as it is closer to real-world problems than VRP. Between 2000 and 2015 number of scientific papers in the field of DVRP has rapidly grown due to the development of information and communication technologies. Scientific interest continued to this day with the development of Industry 4.0 technologies (I4.0). I4.0 technologies that impacted or may impact in future DVRP drastically include the Internet of Things, Cyber-Physical Systems, Big Data, Cloud Computing, etc.

Aims

Currently, VRP and DVRP scientific research is very active, maybe more than ever before. But most papers deal with generic work on idealized VRP models. The industry needs real-life ("rich") models and powerful algorithms to solve them. The aim of the thesis is to construct a new DVRP model that will integrate I4.0 technologies and resemble real-life problems. The real-life DVRP model is expected to help the research results benefit the industry.

Methods

VRP is considered to be an NP-hard problem, so DVRP is considered to be at least an NP-hard problem. That means that optimal solution cannot be calculated in a time acceptable for practical use by exact algorithms. Because of that, finding an optimal solution for both problems often requires the use of heuristic algorithms. Among lots of different heuristics approaches Ant Colony Optimization (ACO) algorithm or its variants is considered by many authors to be a reliable, efficient, and overall good choice for solving DVRP, due to its ability to adapt to dynamic changes. This is because of its inherent ability to memorize past optimal solutions via its artificial pheromone model.

To solve the new DVRP model, it is expected that the ACO algorithm should be improved in one or more ways. Possibilities include enhancing the existing ACO algorithm or creating a hybrid version by combining ACO with one or more different heuristic algorithms.

The methodology is expected to be: create a new model that will describe the new generation of DVRP more accurately, simulate the problem and get an optimal solution using an improved ACO algorithm. Compare results with existing models and solutions.

Expected scientific contribution

Construction of real-life DVRP model. "Solve" new DVRP using improved Ant Colony Algorithm. Real-life DVRP data sets that could be used to test new methods and compare results.

Keywords

dynamic vehicle routing problem, ant colony opti-mization, Industry 4.0

Efficient Ship Operability Analysis and Prediction of Extreme Wave Loads Using Hindcast Wave Database

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Introduction

The method for the prediction of extreme wave loads on ships for long return periods that may be used in ship structural design is presented. A passenger ship sailing from Split to Ancona and vice versa is considered. The ship operability analysis is performed to determine the percentage of time during which the ship may not achieve its purpose. Wave data along the shipping route is obtained from the hindcast wave database, containing 23 years of continuous sea state records. For a return period of 20 years, extreme vertical wave bending moments are determined.

Aims

Currently used methods for long-term prediction of wave loads on ships are based on wave statistics containing probabilities of occurrence of sea states and also assuming a uniform distribution of heading angles. The ship operability analysis is seldom performed to determine the effect of heavy weather avoidance and maneuvering in heavy seas on extreme wave loads. Thus, wave loads determined by direct seakeeping and statistical analysis are often overestimated. To overcome this problem, a historical database of hindcast sea states is used in the present study, together with ship operability analysis. Actual shipping route is used, enabling accounting for realistic heading angles between ship and waves.

Methods

For calculation of transfer functions of ship motions and loads, Jensen's closed-form expressions were used. The required input information for the method are the main characteristics of the ship: length, width, draught, block coefficient, speed, and heading which make this procedure simple. Transfer functions of heave, pitch, roll, vertical motions and accelerations, relative motions and velocities, and transfer function for the wave-induced vertical bending moment are obtained. Hindcast wave database is used to retrieve wave data such as the significant wave height, the peak wave period, and the mean wave direction from the past 23 years. Due to the semi-enclosed Adriatic basin, the JONSWAP wave spectrum, which is a modification of the Pierson-Moskowitz spectrum, is used. For the seakeeping operability criteria calculation, response spectra and moments of the response spectra need to be estimated firstly. After the most probable extreme wave bending moments are calculated, annual maximum extreme wave bending moments are obtained separately for all sea states and only for those satisfying operability criteria. Namely, it is likely that the ship will not sail in sea states for which operability criteria are not satisfied, or the shipping route will be altered in order to avoid such sea states. Consequently, it is very conservative to consider all sea states recorded along the shipping route in determining extreme wave loads. Gumbel distribution is finally used for calculations of long-term extreme wave bending moments for 20 years-long return period.

Expected scientific contribution

The proposed method enables improved prediction of long-term extreme wave loads on ships by accounting for actual sea states recorded along the shipping route in the past and operational restrictions. The procedure will provide the framework for including uncertainties in the ship operability analysis.

Acknowledgments

This work has been fully supported by the Croatian Science Foundation (HrZZ) under the project Modelling Uncertainty of Ship Response Prediction in the Adriatic Sea (MODUS), (Project No. IP-2019-04-2085).

Keywords

Seakeeping operability criteria, operability analysis, wave bending moment, transfer functions, hindcast wave database, uncertainties

Practical Implementation of Predictive Control in Buildings

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Introduction

In recent studies it has been shown that the implementation of model predictive control (MPC) in buildings can greatly improve thermal comfort as well as reduce operational costs of buildings technical systems. Moreover, buildings are expected to play a pivotal role in the flexibility of smart energy grid by using advanced control strategies such as MPC. However, predictive control is still not widely used, mainly due to the ambiguities regarding practical MPC implementation. One way to improve the scalability of the MPC is to reduce the time and expertise required for model setup. However, the true cost of real building MPC implementation remains unknown, since only 20% of research is based on experimental work, while the majority is based on simulations. Setting up a building model for optimal control problem may take up to 70 % of implementation effort.

Aims

To mitigate the complexities regarding model development, in this work, different models will be compared using key performance indicators. They are yet to be defined, but will be based on accuracy, computational time, robustness, smoothness, and reliability. The lowest implementation cost for MPC to be efficient enough is another unanswered question, as well as the criterion of that effectiveness.

Methods

As part of the RCK Ruđera Boškovića project a building designed specifically for the use of the MPC is going to be built. The building will be equipped with over 1000 sensors and have an open source building automation system which will be used to test and validate different MPC formulations. Numerous building models will be developed in MATLAB programming language which will include RC models of different orders, time series transfer functions, Random forests, and artificial neural networks. Moreover, these models will be tested under different practical conditions such as different building excitations, varying occupancy patterns, number of sensors used and training periods.

Expected scientific contribution

By using the existing building for the validation and testing of different MPC problem formulations, the time and expertise needed for the practical implementation of the MPC in the building sector is expected to decrease.

Keywords

model predictive control, building modeling, optimization

Numerical and Experimental Analysis of Ventilation Type Impact on Aerosol Dispersion in a Room

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Introduction

The pandemic of SARS-CoV-2 had a vast impact on global health system, economy and other aspects of our life. In the early stages of pandemic, transmission through direct person-to-person contact and large droplets were considered to be the main sources of infections. Adequate hygiene and social distancing can play an important role in solving those problems. Third way a virus can spread is through aerosols, small droplets with diameters bellow 5 μm, which can linger in the air for couple of hours and can carry a virus for tens of meters away from infected person.

Aims

Ventilation can be used for controlling the virus dispersion in a room, i.e. prevent cross infection between people. Aerosols are mostly affected by the room airflow, but what type of ventilation system is most efficient in diluting aerosols is unknown. Computational fluid dynamics (CFD) represents a practical way for engineers to research the movement of air in space.

Methods

In this research, ANSYS Fluent software package will be used for numerical analysis. In order for CFD analysis to be relevant, models that were used in numerical analysis need to be validated and verified. For that reason, experiments need to be conducted. Tracer gas method will be used for simulating exhaled aerosols, and measurements will be carried out in "RCK Ruđera Boškovića" building. Four different ventilation systems (mixing ventilation, displacement ventilation form side walls, displacement ventilation from floor and natural ventilation) with varying air flow rates will be tested.

Expected scientific contribution

Researchers have published many papers dealing with ventilation and its influence in virus spread control, but there is still no consensus regarding what type of ventilation is superior in preventing the virus spread via aerosols, which will be investigated in this research.

Keywords

airborne transmission, numerical analysis, experimental analysis, ventilation

Cooperative Cargo Transfer by Drones: Sensitivity Analysis of Drones Thrust Forces for the Class of Geometries of Equal Loads

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Introduction

Unmanned aerial vehicles (UAV), i.e., drones, are used for delivering and transport different types of cargo. For cargo delivery without landing, suitable is a model of cooperative cargo transfer by drones, in which the cargo is linked to the drones with non-extensible ropes. The carried cargo is connected with each of the drone by one rope. The ropes are of equal length and negligible mass. UAVs and cargo are shown as material points in space. The forces, in this model, are shown as the forces acting at these material points. The reference position in the coordinate system is the position where the drones are axisymmetrically in relation to the direction of flight, at equal altitudes, and the cargo is in between of them. Such geometric configuration is described by the angles between the coordinate axes and the action directions of the model forces. The system moves at a constant speed in an uncharacterized environment, and it is sensitive to the impact from the external environment. For example, sudden gusts of wind can change the reference geometric configuration and disrupt flight stability. A change in the geometric configuration of the model leads to a change in the amount of a drone thrust forces. Unevenly consuming batteries impairs flight stability and safe cargo delivery. For a stable model, it is assumed that the load of the drones is equal. The load factor, defined specifically for this physical model, is described by geometry parameters, i.e., the angles that describe the model. The equal load of drones is achieved not only for the desired, reference flight mode but also for different geometric configurations that deviate from the reference position. For that reason, it is possible to talk about the class of geometries of equal loads of drones. The sensitivity of the thrust forces of drones, to small changes of model angles, is different for different geometric configurations.

Aims

The aim of this research is to develop a method that efficiently examines the static sensitivity of drone thrust forces for geometry class of equal loads. This will be done with respect to the change of parameters which describing the geometry of the model. That changes are the result of the external impact from the environment.

Methods

The theoretical model of the described cooperative transfer of cargo by drones is completely solved. Expressions for the thrust forces of the drones are connected via the expression for the load factor. Static sensitivity method has been applied to analyze the influence of the external environment on the thrust forces of drones. Estimation was performed by monitoring the changes in the angles of this model, for the class of geometries of equal load. After the estimating the static sensitivity of the thrust forces of drones, a comparison of the obtained results was performed.

Expected scientific contribution

The work will demonstrate which geometrical configuration of the model is most sensitive to an external impact of the environment.

Keywords

Unmanned aerial vehicles, drones, static sensitivity, sensitivity analysis, load factor

Impact of Non-Road Mobile Machinery Emissions in Comparison to Emissions from Road Vehicles

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Introduction

Global emissions are rising, and with their harmful effect on climate change and human health, additional policies must be enacted for them to start decreasing. Emissions from non-road mobile machinery (NRMM), although having a significant proportion in total emissions, have been neglected in research and policy making. While more stringent legal restrictions of engine exhaust emissions have been implemented on engines in NRMM, there is a lack of data which would enable researchers and policy makers to adequately monitor the effect of those restrictions. Most countries do not have emission inventory for NRMM. Those who do, base their inventories on little data, mostly using assumptions. An overview of some existing NRMM emissions inventories, and their comparison to inventories for road vehicles, would provide the necessary context, i.e., show that NRMM have a larger proportion in total emissions compared to their proportion in total energy consumption.

Aims

The aim of this research is to give an overview of some of the existing NRMM emission inventories and to compare them with the respective emission inventories for road vehicles. This comparison would show that a more serious approach is needed for their emission reduction, since they have a significant proportion in total emissions. Furthermore, since most of this machinery is construction, agricultural and household machinery, they have a significant health impact on people which operate them. New policies, backed with constructive research and government-provided resources for data collection would have a major impact on monitoring and reducing NRMM emissions.

Methods

Firstly, data for six countries which have existing NRMM emission inventories will be collected: Netherlands, Germany, Finland, Sweden, Switzerland and Denmark. Where possible, data will be collected from the official bureaus of statistics. Furthermore, data on emissions from road vehicles will be collected.

Secondly, NRMM emission will be compared to the ones of road vehicles. Main NRMM emission emitters are going to be distinguished and possible solutions for data monitoring and policy planning are going to be presented.

Thirdly, differences of NRMM emission inventories are going to be researched, in order to provide conclusions on reasons for data discrepancies among different countries. This would enable easier planning for future data monitoring.

Expected scientific contribution

Lack of data is the main reason for imperfectionof existing NRMM emission inventories. Without even a repository of NRMM there can be no systematic approach to solving the problem of their disproportionate emissions. There will be a continuation of neglect and underestimation of NRMM emissions, with only sporadic research and suboptimal policies. This research will clearly show the importance of a systematic approach to NRMM emission reduction and provide explanations for a discrepancy of existing data.

Keywords

Internal combustion engines, emission factors, non-road mobile machinery, emission inventory

Improving Odometry Based Localization of Mobile Wall-Climbing Robot Using Sensor Fusion Based on Machine Learning

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Introduction

In recent years there is an increasing need for robots that are capable of autonomous inspection of vertical structures like bridge columns. For a robot to be able to perform an autonomous inspection on vertical structures, it must have a robust adhesion and localization system, as these are prerequisites for a good navigation system. Localization is an estimation of robot position and orientation of which this information can be acquired from sensors and other systems. There are two types of localization, relative and absolute. A relative localization system, usually known as dead reckoning, estimates mobile robot position and orientation by integrating information produced by the robot's onboard sensors, like encoder and inertial sensors. Absolute localization system estimates mobile robot position and orientation using its environment. These localization systems include GPS, LiDAR, visual odometry based on markers and/or environment features, etc. The main problem with a mobile climbing robot is that they often cannot rely on an absolute localization system because of the environment they are operating in, like poor GPS signal strength, a few environment features, inability to place visual markers, etc. That means that most of the time mobile climbing robots must rely on relative localization systems, using odometry and dead reckoning. The problem of the relative localization system is error accumulation that leads to a poor localization system.

Aims

This research aims to show that odometry-based localization can be improved using sensor fusion methods that are based on machine learning techniques and to prove that sensor fusion methods based on machine learning techniques give improvements in comparison to the classical sensor fusion techniques like Kalman Filter and Complementary filter.

Methods

In the scope of this research, it is planned to develop a classification algorithm based on a deep neural network that can detect most of the systematic and non-systematic errors coming from encoders due to wheel-slip, uneven surface, unequal wheel diameter, etc. Another method that will be developed is a classification algorithm based on a deep neural network that can detect IMU drift and sensor measurement noise. The last method that will be developed is a regression algorithm based on a deep neural network that is capable of predicting robot position error using information from sensors and two classification algorithms mentioned earlier. Performance improvement of these methods can be tested by comparing robot localization when it is using developed methods and when it is using classical odometry-based localization methods. For tests to be valid, robot estimated localization must be compared to the ground truth data. Ground truth data can be acquired by a laser tracker, that is capable of tracking robots' absolute position.

Expected scientific contribution

The research is expected to provide a new sensor fusion method that is based on machine learning and can be implemented not only on wall-climbing robots but in general high-accuracy mobile robotics applications. This method will improve the robot's localization which will have an impact on improvement on the robot's navigation.

Keywords

Localization, Odometry, Machine learning, Sensor fusion, Wall climbing robot, Autonomous inspection robot

Numerical Analysis of Air Flow in the Room for the Purpose of Assessing Thermal Comfort

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Introduction

Nowadays, in most cases, heating, ventilation, and air conditioning system designers design a room air distribution system using simple diagrams that estimate the speed of airflow in the room based on the position of the ventilation air diffusers on the ceiling. The airflow rate is usually determined at a certain point below the air diffuser itself. This approach has many disadvantages: the parameter affecting thermal comfort is not only the air velocity but also the air turbulence intensity, the position of a person is assumed in the middle between two air diffusers which means that the turbulence intensity is estimated at only one point of space, thermal comfort cannot be assessed without analyzing the person's influence on airflow, which can be significant. The development of an approach based on computational fluid dynamics would eliminate a large number of shortcomings of the existing approach and open space for further research in this direction. It is expected that the concept of the dependence of thermal comfort on the air distribution system will be improved by applying computational fluid dynamics.

Aims

The research aims to find the concept of thermal comfort dependence on the room air distribution system by numerical analysis of airflow for various variants of air diffusers, the position of a person to air diffusers, and temperature differences of supply air and room air. Research will cover the influence of: asymmetric flow of air jets into the room due to asymmetric construction of plenum and connection of air distributors to the air duct, influence of flow in a room depending on the mutual distance of diffusers whose jets interact, the influence of geometric and thermal model of person in room on flow and influence of flow on thermal comfort through parameters: air flow rate, air temperature with a person in terms of the amount of temperature and its distribution along the surface of the computational thermal manikin model.

Methods

The first phase involves the analysis of airflow (using computational fluid dynamics) for cases when there are multiple air diffusers in the room, which results in a collision zone of multiple air jets. The second phase involves the implementation of a person's model in a numerical simulation and the determination of thermal comfort based on the results obtained by numerical analysis. Applying computational fluid dynamics temperature, air velocity, and turbulence intensity are determined. 3D numerical models are created. The flow is modeled with Reynolds-averaged Navier–Stokes equations (RANS). Polyhedral and tetrahedral unstructured meshes are created. If necessary, hexahedral structured numerical mesh will be used. Spatial discretization is solved by the finite volume method. RNG-ke and kw-SST turbulent models are used. If necessary and feasible in terms of computer performance, LES will be accessed.

Expected scientific contribution

Only numerical analysis can give a complete picture of the airflow in the zone in which several jets of air interact. It is expected that the numerical analysis will provide a more detailed distribution of air temperature, air velocity, and turbulence intensity in a room with mixing ventilation, which will allow a more precise assessment of thermal comfort compared to the conventional approach.

Acknowledgments

I would like to thank Klimaoprema d.d. who is also part of the project within which this doctorate thesis is being carried out.

Keywords

3D numerical model, CFD, thermal comfort, air-jet collision zone

Testing of Anticorrosive Properties of Conversion Coating and Powder Electrostatic Coating on Different Types of Electric Resistance Welds

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Introduction

Corrosion of metal surfaces is inevitable, so it is needed to be prevented by a proper corrosion protection method. Powder coatings are effective way to prevent corrosion in metal parts. Critical areas on the structures are welded joints which can have negative effect on the coating durability due to different weld geometry and deformations. The aim of this work was to investigate the corrosion resistance of several electro-resistant weld types. Coating was performed at an electrostatic powder coating plant. All samples were treated under the same coating parameters, the difference is the chemical pre-treatment (phosphate and zirconium) and shape (appearance) of the welds. Namely, three weld types participated in the testing: 1. welds with minimal or no deformation, 2. welds with a slight degree of deformation, while the 3. weld type had significant and very significant deformations (needles, protrusion, foamy deformations). Research included salt spray test, microscopic analysis, and electrochemical impedance spectroscopy. Results of this work showed that phosphate conversion coating under epoxy-polyester coating is better for anticorrosion durability of spot-welded wire products that have significant weld deformations.

Aims

The aim of this work was to investigate the difference in properties of zircoium and phosphate conversion coating in combination with powder coating on several electro-resistant weld types.

Methods

The test methods of this paper consist of electrochemical impedance spectroscopy, stereomicrographic analysis of electric resistance welds and salt spray chamber testing.

Samples of electric resistance welded low-carbon steel wires were used for stereomicrographic analysis of the coating at the weld site. Samples of 81 electro-resistant welds are used, so that the sample contains three types of welds according to the degree of deformation: with minimal deformations, with slightly more deformations and with significant deformations in the form of foams and needles. Appearance analysis of each type was performed stereomicrographically across the cross section of the welded joint. A cross section of the welds was made on a sample to which a conversion coating and an organic (epoxy-polyester) coating had been previously applied. It is assumed that welds with higher deformations require better surface protection since they are of different microstructures.

In the salt chamber the anticorrosive durability of these types of welds were examined with respect to the type of conversion coating.

The electrochemical impedance spectroscopy test was performed to compare the influence of phosphate and zirconium conversion coating under the same type of epoxy-polyester coating on the surface protection properties. Measurement of the resistance properties of the coating was performed on two wire samples. It would be optimal if the weld area is immersed in the medium, but the wire was chosen for this test because it is necessary to have the exact area in contact with the medium in which it is immersed, while for another sample form the exact area cannot be calculated without additional tools.

Expected scientific contribution

This work contributes with an evaluation of anticorrosive properties of phosphate and zirconium conversion coating in combination with powder coating and it's performance on different electric resistance welded steel wires.

Keywords

powder coating, corrosion, organic coatings, chemical pre-treatment, salt spray chambe

Calibration of a 7R Joint Sensing Collaborative Robot with Serially Linked Joints

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Introduction

Recent years saw an increased focus on development and introduction of collaborative robots, so called cobots, which enable humans to work in the same work environment with the cobots, without the need for safety fences or any other kind of additional safety devices. Among these, of special interest are those configured with joint sensing capabilities, providing both safety and compliancy functions. This is achieved by implementing torque sensors into each of the robot joints, thereby sensing the strain of each of the joints as torque is exerted upon it through the links of the robot. This functionality opens an entire new field of compliant and sensitive applications, however, all cobots of this type introduced so far have up to an order of magnitude lower repeatability, reducing also absolute accuracy compared to standard industrial robots. This limits their applicability in applications where positioning accuracy is of high importance, while compliant and safety features would be beneficial.

Aims

The aim is to obtain calibrated kinematic and non-kinematic stiffness parameters which fit the robot's kinematic model more closely to the real robot, eliminating the majority of kinematic and part of non-kinematic errors, thereby significantly improving absolute positioning accuracy.

Methods

Research is conducted on a KUKA LBR Med 7 joint sensing collaborative robot with a serially linked 7R configuration. Compared to standard 6-axis industrial robots, the redundancy introduced through the additional 7-th axis complicates the calibration process and model definition. For this reason, a different approach for denoting robot configurations is used, enabling unambiguous record of the arm configurations as well as simplifying kinematic calculations. Calibration setups often utilize very expensive equipment, however for this initial research the robot's joint sensing capabilities shall be used to eliminate the need for external measurement devices. The kinematic model is defined using the Modified Denavit-Hartenberg method, with an additional non-kinematic parameter modelling joint stiffness. Parameter optimization is performed using the fmincon function from MATLAB's Optimization Toolbox.

Expected scientific contribution

Not much research as of yet has been done on 7-axis robot calibration and as far as we are aware this is the first time this configuration denotation and kinematic definition is used in robot calibration. Also, by primarily using the robot's joint sensing capabilities the research is expected to produce a simple and effective calibration method, requiring no additional expensive measurement devices, with investment for referencing tools expected to be minimal to none.

Keywords

robot, collaborative, calibration, Denavit-Hartenberg, stiffness

Hemodynamics of Vascular Flows

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Introduction

Hemodynamics has been shown to play a crucial role in the progression of arterial diseases such as aneurysms and dissections. Computational fluid mechanics has shown its potential as a powerful modelling tool for understanding vascular disease progression. At present, most hemodynamics research is focused on modelling blood flow while assuming a rigid arterial wall, even though this assertion is not necessarily justified. Considering the existing discrepancies between clinical observations and numerically obtained results, it is prudent to include wall compliance within models. Efficient solution procedures for vascular flows while considering wall deformation, i.e., fluid-solid interaction simulations, require adequate solid-phase solvers. Existing finite volume-based solvers exhibit convergence and stability issues for problems of incompressible finite strain and unstructured meshes, which commonly occur when modelling arterial tissue. Similarly, available fluid-solid coupling algorithms suffer from numerical issues, resulting in lengthy simulation times and questionable accuracy.

Aims

The primary goal of this research is to develop a numerical procedure with which fluid-solid simulations in vascular flows can be efficiently performed. The first step is the development of a novel solid-phase solver, capable of handling large deformations and hyperelasticity. The following step includes the development of an efficient fluid-solid coupling algorithm with which accurate simulation results can be obtained within reasonable time frames. Finally, both the solid-phase solver and the fluid-solid coupling algorithm need to be verified against analytical and experimental data.

Methods

The numerical framework will be developed using the finite volume approach and implemented within the open-source computational fluid dynamics code OpenFOAM. The subsequent verification will require the development of an experimental setup which will simulate realistic arterial flow conditions and allow for measurements, such that relevant data can be acquired.

Expected scientific contribution

The development of a robust fluid-solid simulation framework will allow for more detailed hemodynamic analyses giving greater insight into the progression of arterial diseases. Such a numerical procedure would also enable the long-term goal of developing a diagnostic tool usable in medical practice.

Acknowledgments

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Keywords

Hemodynamics, Fluid-Solid Interaction, OpenFOAM, Finite Volume Method

Comparison of VOF and Level Set Methods for Simulating Ship Self-Propulsion in Full Scale Using the Overset Mesh Approach

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Introduction

Accurate prediction of the self-propulsion point of the ship represents a challenging task in modern shipbuilding. The significance of this task is important considering the regulations regarding lower greenhouse emissions. CFD studies of ship self-propulsion can be performed both for model and full scale. Due to differences in Reynolds numbers, model and full-scale flow fields differ significantly. For the sake of efficiency of the numerical approach, the propeller is modeled as an actuator disc. However, if detailed flow features around and behind the propeller are of primary interest, the ship propeller can be modeled as fully discretized and rotating using the sliding mesh interface or dynamic overset grids. The actuator disc approach is sufficient for self-propulsion analysis, as integral values such as thrust and torque will be well estimated. Overset mesh approach uses multiple separately meshed grids, usually one background and one or more body grids, to discretize the computational domain. Interpolation of the field data between the grids is performed in the fringe layers. The use of the overset mesh approach has advantages in the computations of moving and multiple bodies. In this work, the overset approach is used to conduct steady-state self-propulsion simulations for the purpose of testing the method, as the first step towards self-propulsion simulations with a rotating propeller.

Aims

The objective of the presented work is to compare and validate the developed CFD methods for the scope of the prediction of the full-scale ship self-propulsion point using the overset mesh approach, and also propose possible improvements.

Methods

Volume of Fluid (VOF) and Phase-field based Level Set (LS) methods are being used in this work. Ghost Fluid Method (GFM) is used for modeling the free surface boundary conditions, i.e. to take into account pressure gradient and density jump across the interface. The VOF approach uses implicit discretization of volume fraction advection equation with interface compression. The LS method is based on the Phase Field equation with implicit re–distancing. The two-equation k-omega SST model is used for turbulence modelling. The computational domain consists of background mesh, and mesh fitted to the ship hull.

Expected scientific contribution

The presented work is focused on the comparison and validation of two developed CFD methods (VOF and LS) in the scope of the prediction of the full-scale ship self-propulsion point using the overset mesh approach.

Acknowledgments

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Keywords

VOF, Level Set, Overset mesh, Full-scale, OpenFOAM

Piezoelectric Lattice Model

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Introduction

In modern times, "smart" systems are applied in many areas. Such systems can sense a certain external stimulus and need to respond to it in a predetermined manner, which is why they need to be equipped with a range of sensors and actuators. Because piezoelectric materials have a strong electromechanical coupling, they are mostly used as parts of these sensors and actuators. Such materials are mostly quasi-brittle, so it is necessary to know their behavior during damage and fracture, to be able to estimate their service life. There are many complex numerical procedures based on the continuum approach to properly model the damage of such materials at lower scales. As a simpler alternative to these models, lattice models are developed, where the continuum is represented by a number of rigid particles which interact through one-dimensional elements that represent cohesive forces between particles. The softening of real material in such models is achieved by activating the discontinuity in the displacement and strain fields when the stress in a particular element reaches a limit value.

Aims

One-dimensional finite element will be developed that, embedded in the lattice model, will be able to describe the behavior of real material, regardless of the direction of polarization and the way of loading the real material. For such elements, it is necessary to derive material parameters depending on the geometry of the element itself, which can well describe the global behavior of the whole model.

Methods

Depending on the topology, the lattices can be regular or irregular. Although with regular lattices it is easier to determine the parameters of the elements to describe the uniform straining, irregular lattices are more often used in the study of damage and fracture, because they are better suited for capturing the direction of crack propagation correctly. Piezoelectric truss and beam finite elements are used as lattice elements. In these elements, a discontinuity is added to the fields of displacement and strain, the activation of which begins the exponential softening of the element.

Expected scientific contribution

Lattice models have proven to be faster in passive materials than classical continuum models for damage and fracture modeling, so the same can be expected also in piezoelectric materials.

Keywords

piezoelectric materials, lattice model, discontinuity, softening

Numerical Modelling and Experimental Investigation of Sintered Material Fatigue Behaviour

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Introduction

The advanced materials usage in recent years, along with acceptable production costs, plays a significant role in modern structures and machine components. In power transmission systems, powder metallurgy presents significant advantages in comparison with conventional metallurgy. However, the porosity of the sintered materials causes stress concentration, strain localization and damage accumulation in microstructure, which promotes material fracture. To investigate initiation and crack propagation, the phase-field (PF) method in recent years gained huge popularity due to the fact that no ad hoc criteria is required.

Aims

Using numerical phase-field method, investigation of micro-crack initiation and propagation of sintered steel samples will be conducted based on monotonic and cyclic loading scenarios. Comparison with different experimental procedures on micro- and macroscale will validate phase-field method.

Methods

Using metallography images of the polished surface, porous 2D homogeneous and heterogeneous models are created. Three different size models are chosen to investigate inter- or trans-granular crack. Empowering sharp instrumented indentation method on the microlevel, material properties of each crystal grain are determined. To determine the tensile elasto-plastic properties of each crystal grain different analytical methods are combined to reconstruct the indentation data. Using latter mechanical properties heterogeneous models are compared to homogeneous ones and size-effect is determined. Later, ex-situ computed micro-tomography is used to reconstruct real 3D model from tensile specimens. In this way, quantitative and qualitative comparison of numerical phase-field method is enabled.

Expected scientific contribution

A new approach for quasi-static and fatigue crack modelling on sintered material micro- and macroscale will be presented. Also, a more accurate numerical damage modelling, in relation to existing algorithms, allows prediction of reliability and safety of mechanical components.

The use of derived procedure allows a new sintered and porous advanced property material development along with advantageous microstructure which contributes the manufacture of sintered mechanical components for demanding loading condition.

Acknowledgments

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Keywords

sintered material, Phase-field method, multiscale modelling, crack prediction, fatigue crack propagation, instrumented indentation, computed tomography, tensile test

Primary Realization of the Temperature Scale from the Triple Point of Argon to the Triple Point of Water

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Introduction

The International Temperature Scale ITS-90 is currently the closest possible approximation of the thermodynamic temperature. In the range from -272.5 °C to 1085 °C, the scale is defined through set of thermometric fixed points. Those are melting, freezing, triple or vapor pressure points of very pure chemical elements. The focus of this research is the triple point of argon (-189.3442 °C) as the lowest point for calibration of long-stem platinum resistance thermometers. Through the development of the system for realization of the triple point of argon, primary realization of ITS-90 is extended towards the cryogenic region. This sets ground for further scientific research in the field of low temperature metrology and enables involvement in the process of improvement of the thermodynamic temperature approximation.

Aims

The aim of this doctoral research is independent primary realization of International Temperature Scale (ITS-90) from the temperature of the triple point of argon (-189.3442 °C) to the triple point of water (0.01 °C). This includes design and characterization of measurement system for realization of the triple point of argon, defining of the corresponding experimental method and procedure for realization, and measurement uncertainty assessment of the system. Through this research, traceability of the temperature measurement below triple point of mercury (-38.8344 °C) will be ensured. Also, direct traceability of primary dew/frost point generator, used as national humidity standard, will be achieved.

Methods

Measurement system for the realization of triple point of argon will be designed and assembled. Main parts of the system for realization of the triple point are sealed fixed point cell filled with argon and cryostat, filled with liquid nitrogen. Manual regulation of the pressure in the cryostat, will be replaced with automatic one, to ensure more flexible control of the temperature of nitrogen phase transition. This will enable easier and more accurate achievement of triple point state of argon in the cell. All subcomponents of the system will be characterized and harmonized, to ensure the lowest possible measurement uncertainty of the realization. Uncertainty budget will be composed with the investigation of all relevant contributing parameters. Numerical model of the fixed point cell will be used to determine effects of the conditions in the cryostat on the triple point state of argon. Overall performance of the system will be verified through intercomparison with the equivalent temperature standard.

Expected scientific contribution

Through this research new measurement system for primary realization of temperature of triple point of argon will be developed, with internationally affirmed measurement uncertainties. Along with the system, complimentary experimental method, ensuring longest possible melting plateau of argon, will be designed and tested. Improved pressure regulation system in the cryostat will ensure optimal condition for triple point realization.

Keywords

Temperature measurement, triple point of argon, ITS-90, measurement uncertainty

Comprehensive Analysis of Damage in Fiber Reinforced Polymers

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Introduction

Fiber reinforced polymer (FRP) composites surpass the limitations of conventional engineering materials, as their heterogeneous microstructure can be engineered to meet the specific design requirements. The complex and heterogeneous architecture of such materials induces various damage mechanisms at different length scales. This calls for comprehensive analysis of bulk kinematic changes, which is essential to understand the role of microstructure on the failure of FRPs. Digital Volume Correlation (DVC) has recently emerged as an efficient technique allowing displacement (and strain) fields to be measured in the bulk of various materials by registering 3D images (e.g., obtained via X-ray computed tomography (XCT)). Furthermore, as in surface observations (via Digital Image Correlation), global approaches, which assume the continuity of the displacement fields, were introduced. Such framework enables for the measured displacements to be coupled with finite element (FE) simulations.

Aims

The aim of the research presented herein is to perform a comprehensive analysis of damage growth within epoxy resin reinforced with glass fiber mat. FE-based DVC was employed to measure 3D bulk kinematics. Opposed to local approaches, gray level residual maps (i.e., differences between the reference volume and the corrected deformed one) are available from the correlation runs. Since DVC assumes gray level (GL) conservation, correlation residuals serve as a correlation quality inspection tool. Moreover, GL residuals provide information crucial for damage detection. Hence, the analysis of correlation residual maps enables for the extent of damage processes to be assessed within the material bulk.

Methods

In situexperimental study was conducted to measure the bulk kinematics of the specimen subjected to cyclic tensile loading from reconstructed scans registered with a laboratory X-ray scanner. Dogbone sample was machined from the composite plate and thinned in the central part with a radius of 49 mm to ensure the sample breaks in the narrowest gauge section. 3D displacements and strains were measured employing global (FE-based) DVC approach. One of the main advantages of XCT is to reveal the bulk microstructure. In this regard, the calculated eigen strain fields and correlation residual maps studied to track damage inception and growth within the investigated region of interest (ROI) can be related to microstructural features.

Expected scientific contribution

The obtained results underline the importance of in situ bulk measurements in the damage analysis of FRPs opposed to surface measurements. Namely, damage initiates in the bulk and subsequently propagates on different length scales. The proposed measurement tools enable for the precise identification of damage mechanisms inducing FRP failure. Finally, the damage processes can be related to the complex microstructural architecture of the proposed material.

Acknowledgments

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Keywords

Glass fiber reinforced polymer, Damage, Digital Volume Correlation, Gray level residuals

Development of Composite Sandwich Structures with Aluminum Foam Core

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Introduction

Due to their high porosity, Al foams have a much lower density and mass compared to the basic Al. In addition to low density, Al foams have some other properties that are very interesting for their application, such as excellent stoke, vibration and sound absorption, good fire resistance and electrical conductivity. Due to the very high energy absorption characteristics, they are used in vehicles to protect passengers, but also in ballistic defense. Because of the low modulus of elasticity and relatively low compression strength, Al foams are very often used as cores of sandwich structures where the walls take over high static and dynamic loads and the core increases stiffness. Unlike periodic cellular metal sandwich structures that have good mechanical properties only in the direction in which the cells are directed, sandwich structures with an Al foam core show more isotropic mechanical properties in the multiaxial stress state.

Aims

The aim is to determine how the relative density of Al foam and wall material affect the properties of composite sandwiches with outer layers made of different materials and to choose the optimal combination of sandwich materials for a particular purpose. The methods of joining the Al foam and the surface layers will also be studied, to choose a strong bond with satisfactory mechanical resistance.

Methods

The production of Al foams consists of heating the precursor in the mold to the temperature where foaming begins. The precursor is a compacted Al powder mixed with a foaming agent (titanium hydride, TiH_2) which is activated at higher temperatures and causes foaming. By placing different quantities of precursors in the mold can give different degrees of porosity of the foam. After heating and foaming, the mold is taken out of the furnace and the foam is extracted from it. One way to make a sandwich structure with Al foam core is to glue the outer layers to the already made foam. Another method is to place the precursor in an already finished mold that will represent the outer layer of the sandwich structure and to heat them together. By examining the mechanical properties, the degree of delamination for different joining methods will be determined.

Expected scientific contribution

Further development of such composites will determine the best material for the outer layers of the sandwich structure, the optimal porosity degree of the Al foam and the method of joining such layers. The obtained results will contribute to improvement of mechanical properties of such structures primarily greater strength to density ratio and greater energy absorption capacity, which will enable their specific application in different branches of industry (mechanical engineering, shipbuilding, aviation, automotive, etc.).

Keywords

Aluminum foams, sandwich structures, cellular materials, mechanical properties

Phase-Field Modeling of Fatigue

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Introduction

One of the most common failure modes is a failure due to fatigue. Traditionally, fatigue crack initiation and propagation are assessed using relatively simple empirical methods suitable for simple engineering problems. Since the complexity of structures is increasing, more sophisticated methods should be developed for more accurate solutions and increased safety. For the last two decades, the phase-field method for fracture phenomena has been developed. The phase-field method relies on a variational approach to fracture which is a generalization of Griffith's theory, and crack growth is governed by energy minimization conditions. Crack is described approximately using continuous phase-field and the crack surface is approximated using appropriate volume integral, and thus, the complexity of exact crack description is avoided. The resulting method is objective and thermodynamically consistent. Also, the method is capable of capturing complex cracking phenomena, including initiation, branching, merging, etc., without any ad hoc criteria. The Phase-field method can be extended to ductile fracture, dynamic fracture, fracture under finite strains, shell and plate fracture, etc., and is recently extended to fatigue. Recently developed phase-field fatigue methods are an extension of the phase-field fracture model, where the critical energy release rate is degraded using function dependent on deformation history. As those models are capable of naturally capturing some basic fatigue features such as Paris curves and Wöhler curves, there is a potential for further development and a more accurate description of fatigue using the phase-field method.

Aims

This research aims to develop a new fatigue method based on the phase-field method with the capability of reproducing various important fatigue features accurately and numerically efficiently. Reproduced fatigue phenomena would include both crack initiation and propagation laws under complex loading. Both proportional and nonproportional loading will be considered, together with the effect of mean stress and multiaxial stress states taken into account. The main effort will be put into high-cyclic fatigue. Experimental validation of the method will be performed.

Methods

The main numerical procedure based on the finite element method is written in MATLAB. Part of the code is written in Fortran. The solver procedure is based on a robust multi-pass staggered algorithm with convergence control. Minimization of computational requirements, while maintaining accuracy will be obtained by utilization of adaptive remeshing. Further computational time savings for high-cycle fatigue simulations will be obtained with the cycle-skipping algorithm. During the experimental part of the research, a high-frequency pulsator will be utilized.

Expected scientific contribution

The main contribution of this work will be a novel method for fatigue based on the phase-field method for fracture. The method will allow realistic simulation of crack initiation and propagation for arbitrary geometries and loading conditions. Adoption of this method would lead to an increase in the safety of dynamically loaded structures.

Keywords

phase-field method, fatigue, crack growth, crack ini-tiation

Modelling of Pitting Phenomena on Sintered Steel Gear Tooth Flank by Phase-Field Method

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Introduction

One of the most used driving elements for power and motion transmission are gears. In general, gear teeth in gear mesh are subjected to rolling-sliding contact in elastohydrodynamic lubrication (EHL) conditions. Due to rolling-sliding contact, after a certain number of cycles, different types of fatigue damage mechanisms occur, such as pitting, tooth root fatigue and wearing.

Aims

The objective of research is development of novel multiscale scheme for assessment of gear lifetime until formation of pitting on tooth flank and validation by experimental testing. Therefore, numerical phase-field method will be used for more precise modelling of fatigue damage on the gear tooth flank. Also, the novel approach for describing elastohydrodynamic lubrication will be considered for more precisely teeth flanks loading in the rolling-sliding contact with full film lubrication.

Methods

In order to simulate the pass of a gear tooth through a gear mesh in the presence of lubricant in numerical models, tooth flank is loaded by pressure distribution satisfying elastohydrodynamic lubrication conditions, which travels along the tooth flank in several configurations. The EHL model is embedded into the ABAQUS software package within DLOAD user subroutine. The friction force, obtained by Coulomb's law, is embedded by means of UTRACLOAD subroutine. Model of 2D gear tooth flank is discretizated with 2D mixed quadrilateral finite elements. The above-mentioned mixed quadrilateral finite element employing the phase-field variable as a nodal degree of freedom is embedded into ABAQUS within UEL subroutine. For assessment of topological properties of microstructural geometry of sintered steel material, metallographic study is be conducted. For obtaining of the material properties of every microconstituent, nanoindeting testing is performed.

Expected scientific contribution

A novel computational framework for assessment of pitting formation on the tooth flank, which explicitly considers influence of the material microstructure, will be developed. Therefore, a more precise modelling of tooth flank loading will be considered due to rolling-sliding contact with assumption of full film lubrication. Also, more realistic description of the pitting damage on the gear tooth flanks will be performed by utilizing phase-field method.

Acknowledgments

This work has been fully supported by Croatian Science Foundation under the project "Multiscale Numerical Modelling and Experimental Investigation of Aging Processes in Sintered Structural Components" (MultiSintAge, PZS-1 2019-02-4177).

Keywords

pitting, gears, phase-field method, EHL theory

Towards Increase of Autonomy and Energy Efficiency of the Short-Sea Shipping Sector in the Adriatic Sea

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Introduction

Rapid technological development, wireless communication and monitoring, growing environmental awareness, alternative fuels, and stringent regulations are continuously pressuring maritime transportation and shipbuilding. The maritime sector is exploring ways to reduce cost and emissions but at the same time to increase the safety and energy efficiency. Autonomous shipping is an emerging topic, where technical, economic, safety, and environmental aspects are still not mature enough to significantly increase the percentage of autonomous vessels in the global fleet. The reduced crew onboard brings savings and a lower risk of human-induced errors that can lead to human casualties and environmental disasters. However, fully autonomous vessels monitored from the shore require a high-quality and reliable communication system. The technologies needed for autonomous navigation already exist and it is necessary to find the optimal way to combine their safety, reliability, feasibility, and cost-effectiveness. It is also important to investigate what types of ships and which trades are suitable for autonomous shipping. Short-sea shipping is an ideal candidate for developing and testing new technologies due to shorter routes, low energy demand, and frequent port calls. The Croatian Adriatic coastline with numerous islands and a high population is extremely sensitive to marine pollution. Many ferry lines that connect the mainland with islands, and islands with each other are of crucial importance for local population and tourists. Preliminary results show that the Croatian fleet is outdated and it is important to start planning its modernization.

Aims

The aim of the research is to develop a model for a power system of autonomous low-emission ro-ro passenger ship according to modern design criteria as energy efficiency, environmental friendliness, operational safety, reliability, and economy. The functional dependence of these criteria for different degrees of ship autonomy will be developed. Moreover, the possibility of using alternative fuels and renewable energy sources is going to be analyzed.

Methods

In order to assess the impact of the increase of autonomy degree of different power system design, analysis of all costs and emissions will be performed and results will be compared in order to find the best solution. Furthermore, taking into account fuel forecast prices for future and emissions pricing scenarios, under the set of analysis assumptions, conventional and autonomous ro-ro passenger ships will be compared.

Expected scientific contribution

This research will result with a model that can serve as the basis for the investigation of autonomous ships with different design and operative features.

Acknowledgments

This research was supported by the Croatian Science Foundation under the project Green Modular Passenger Vessel for Mediterranean (GRiMM), (Project No. UIP-2017-05-1253). Ivana Jovanović, Ph.D. student, is supported through the "Young researchers' career development project – training of doctoral students" of the Croatian Science Foundation.

Keywords

Autonomous shipping, ship power system, degree of autonomy (DoA), techno-economic assessment, alternative fuel

Analysis of Quenching for Low-Alloy Steels in High-Pressure Inert Gas Atmosphere

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Introduction

Technology of high-pressure quenching in modern vacuum furnaces is constantly progress-ing, every new generation of vacuum furnaces uses higher pressures and gas flow for quench-ing high-alloy steels. Higher pressures and gas flow lead to higher cooling speeds of quenched steel, and with high enough cooling speed new types of steels (steels with smaller percentage of alloying elements) can be quenched. Gas quenching compared to water or oil quenching has number of advantages such as: clean and shiny surfaces, small heat deformations, con-sistent part hardens. Cooling properties for water and oil (liquid mediums) is well understood and tested across the world with jominy quench test, conversely cooling properties for gas quenching, especially for high pressures and flow is not well researched. The proposed study aims to further knowledge of quenching possibilities and cooling speeds for inert gases like argon (Ar) and ni-trogen (N) in high pressure and flow conditions using device made in fur Werkstofftechnik (IWT) institute in Germany. Device is capable of gas quenching using pressures up to 20 bars and gas flow up to 80 m/s. Using different types of steals (with higher percentage of alloying elements to steels with low percentage of alloying elements) and different parameters for pressure and flow, comprehensive insight in quenching and cooling properties will be made.

Aims

Aim of the research is to develop statistical model for evaluation hardenability of different types of steels quenched in high pressure inert gases, and to propose regression model for determining the upper critical quenching speed for medium to low alloy steels heat treated in vacuum furnaces.

Methods

The research plan is divided in these phases: first deciding the type of steel for making test samples on which the quenching curves will be tested. After making test samples, heating parameter (temperature and time of austenitization) will be defined. After defining heating parameters, the test samples will be heated in a vacuum chamber with automatic regula-tion of (quenching gas and chamber) temperature, pressure, flow. Based on the recorded data for tem-perature and time for different test samples during quenching, cooling curve and cooling rate of par-ticular type of steel and cooling gas will be con-structed. From the constructed curves, cooling time and cooling rate from 800 to 500 °C, quenching in-tensity, average heat transfer coefficient will be cal-culated.

Expected scientific contribution

Anticipated methods of statistical analysis and ap-plied model for vacuum quenching different types of steel. Better understanding and systematic methods for quenching possibilities of medium to low alloy steels in high pressure and flow inert gases.

Keywords

Low alloy steel, vacuum furnace, hardenability, nitrogen quenching.

Development of Compact Device for Monotonic and Cyclic Loading Within CT Scanners

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Introduction

Continuous demand for the lightweight structures requires development and use of innovative materials, optimized in terms of mass and mechanical properties. However, existing engineering structures are usually oversized since novel modelling capabilities are limited due to the lack of reliable experimental data. The application of Computed Tomography (CT) in material science provides comprehensive insight into the integrity of the observed object and thus creating the possibility for the design of optimized structures. This non-destructive method implies the use of laboratory X-Ray CT scanners for determination of microstructure on the surface and inside the bulk of the sample. Furthermore, the proposed method is especially important for identification of various damage mechanisms in heterogeneous materials since they initiate on different scales due to the complex architecture of the microstructure.

Aims

The possibility to perform in-situ mechanical test inside the CT scanner is limited primarily by the working area and the loading capacity of manipulation (i.e., rotation) table. The development of the compact equipment for monotonic and cyclic loading within CT scanners remains a challenge.

Hence, the aim of this study is to develop a loading machine for fatigue material testing of fiber reinforced composites within standard industrial CT devices.

Methods

Within this investigation, a loading device will be designed to load the sample with frequencies up to 50 Hz which will ensure the possibility of conducting the entire cyclic experiments in a reasonable time (i.e., approx. one experiment should be performed in one day). The proposed experimental setup will enable performance of series fatigue mechanical tests with various displacement (up to ± 0,5 mm) or force amplitudes (up to 5 kN).

Preliminary tests will be performed to verify the desired performance of the device and to calibrate the work parameters of the proposed loading machine.

The investigated materials subjected to cyclic loading regimes will be characterized regarding their 3D microstructure. Furthermore, the mechanical behaviour of the material will be revealed with the application of full-filed measurement techniques (i.e., Digital Volume Correlation).

Expected scientific contribution

The loading machine for cyclic mechanical testing with the aforementioned features does not exist in a form that allows integration into standard CT scanners. With the application of the experimental equipment developed within this work, monotonic and cyclic in-situ tensile tests will be performed in a unique way. The advanced loading device will allow one to determine initiation and propagation of various damage mechanisms occurring during fatigue loading regimes in the bulk of fiber reinforced polymer composites.

Acknowledgments

This work was performed within the FULL-INSPECT project supported by the Croatian Science Foundation (UIP-2019-04-5460 Grant).

Keywords

lightweight structures, tomograph, material testing, cyclic testing

Optimization of Pre-Chamber Geometry and Operating Parameters of a Spark Ignited Engine

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Introduction

A promising strategy to increase thermal efficiency in an internal combustion engine is the usage of lean mixtures. The flammability limit of lean mixtures can be increased by using an active pre-chamber containing an injector and a spark plug for the mixture ignition. In spark ignited (SI) engines with a pre-chamber, this mode of combustion is most commonly called Turbulent Jet Ignition (TJI) where the ignition of a lean mixture in the main combustion chamber is achieved by the penetration of multiple turbulent jets of combustion products from the pre-chamber. Since the penetration of turbulent jets into the main combustion chamber depends on the pre-chamber and nozzle geometry, it is necessary to define which geometrical parameters are most favourable for pre-chamber SI engine operation in order to achieve minimum fuel consumption. In this paper, the optimization of geometry and of operating parameters with fuel consumption as an optimization criteria was performed for the entire operating range of engine.

Aims

The aim of this study is to determine the most favourable geometric and operating parameters of the engine by using an optimization algorithm which will result in better engine performance and lower engine out emissions.

Methods

To determine the most favourable geometric and operating parameters of the engine the genetic optimization was performed by using the algorithm available in AVL BOOST™ v2013.2, while the combustion process was calculated by using the extended model which takes into account multiple flame propagations in the main chamber. In the first step, operating parameters for the initial pre-chamber geometry were optimized at 9 operating points (3 engine speeds and 3 loads), where the occurrence of knock combustion was controlled at full engine loads. In the second step, simultaneous optimization of pre-chamber geometric parameters for all 9 operating points was performed. In the final step, the values of the operating parameters were optimized using the previously optimized pre-chamber geometry. Results of optimization are compared to initial results of engine performance and raw emissions indicating the improvement of engine efficiency.

Expected scientific contribution

The results of this study will show that the use of genetic optimization algorithm combined with cycle – simulations can successfully determine the most favourable parameters that result in better engine performance which will then support the design phase of the pre-chamber.

Acknowledgments

This work was supported by the Croatian Science Foundation within the project Research of More Efficient and Environment-Friendly Pre-Chamber Spark Ignition Combustion (Project no. IP-2019-04-4900) and "Young researchers' career development project – training of doctoral students".

Keywords

Pre-chamber SI engine, efficiency, optimization, genetic algorithm

APPROVED TOPIC

Influence of Selective Laser Melting Parameters on Structure and Properties of Dental Co-Cr Alloy

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Introduction

Selective Laser Melting (SLM) are used to produce Co-Cr dental prosthodontic appliances (melting layer by layer) like bridges and crowns directly from a 3D CAD model obtained by reversible engineering. Co-Cr alloys possess a combination of good mechanical properties with high resistance to corrosion and wear. The obtained properties of Co-Cr dental alloys depend on the used production parameters such as laser power P [W], scanning speed v [mm s^{-1}], and preheating of working plate T[°C] which can be combined in laser energy density (LED [J mm^{-3}]).

Methods

Specimens were made using an SLM device of the German manufacturer Aconity 3D Mini, which has completely open access to all production parameters. For specimen production were used two different commercially available Co-Cr metal powders for dental use in compliance with all defined requirements according to EN ISO 22674 using own SLM production parameters. Specimens were used for conducting basic mechanical properties. The same specimens were used for light and SEM analysis of microstructure.

Preliminary results

Specimens were made from the two commercial dental Co-Cr powders, with SLM technique with own process parameters, and significant differences in the microstructure and the mechanical properties of the specimens were observed (microhardness, stiffness). The mechanical properties and microstructure of specimens are influenced by the parameters of the SLM process. Results comparison with the current ISO standard 22674 (Dentistry-Metallic Materials for Fixed and Removable Restorations and Appliances. Geneva: ISO, 2016) showed that the tested specimens by mechanical properties generally meet minimum the type 5 criteria in mechanical properties.

Discussion

According to the analysis of the microstructure in the polished and etched state, it was noticed that increasing the scanning speed reduces the proportion of porosity in relation to lower scanning speeds, higher scanning speeds achieve higher relative material density. It can be observed that at lower scanning speeds, the proportion of porosity in the microstructure increases with the increasing preheating temperature of the working plate. Comparing the values of the laser energy density (LED) for a microstructure, it can be concluded that a low LED is not sufficient for complete melting of the metal powder layers, therefore porosity occurs. With higher LEDs, the layers of metal powder completely melt and the porosity decreases, with the possibility of gas microporosity. The microstructure of all specimens has similar characteristics – a homogeneous microstructure with a clear boundary between the grains oriented in the direction of the maximum gradient of heat input. From this, it can be concluded that the SLM processing parameters influence the microstructure and mechanical properties.

Keywordds

Co-Cr dental alloy, process parameters, laser energy density

Constitutive Model for Self-Healing UD FRP Composites

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Introduction

In this work, a micromechanical constitutive model for modelling of intrinsically self-healing fibre reinforced polymer (FRP) composite structures is introduced. The Rule Of Mixtures (ROM) is utilised as a micromechanical model for defining the homogenised composite material, i.e. to define the composite orthotropic elasticity tensor. The matrix constituent is isotropic, and it is modelled using the damage-healing-plasticity model previously developed in (Smojver et al. 2020). On the other hand, the unidirectional (UD) reinforcing fibres are modelled as linear elastic using the transversely isotropic elasticity tensor.

Methods

Finite element software package Simulia Abaqus and the inherent UMAT user subroutine for defining user material constitutive models is used. The UMAT subroutine is written in FORTRAN77. The developed constitutive model is a micromechanical model based on the principles of ROM. At the micro-scale, matrix and reinforcing fibres are modelled individually, each using the corresponding strain tensor. Fibre and matrix strain tensors are defined using the Voigt (iso-strain) and Reuss (iso-stress) approximations. The matrix constituent is modelled as isotropic material using the rate-dependent damage and healing models coupled with the common von Mises linear isotropic hardening plasticity model. Models are coupled using the concept of nominal and healing configuration, and applying the strain equivalence hypothesis, what makes the numerical implementation a relatively straightforward process. Damage variable evolution equation is taken from (Darabi et al. 2011), whereas the healing variable evolution equation is taken from (Abu Al-Rub et al. 2010). Reinforcing fibres are modelled as linear elastic with transversely isotropic elasticity tensor. At the macro-scale, the heterogeneous structure of the composite material is homogenised by applying the principles of ROM. Homogenised composite material is defined using the orthotropic elasticity tensor. Furthermore, additive decomposition of strain, along with Voigt and Reuss approximations, is used to define homogenised composite elastic and plastic strain tensors.

Preliminary results

The developed model is validated with experimental results of three-point bending tests from (Park et al. 2010). The matrix constituent of tested composite specimens is bis-maleimide tetrafuran (2MEP4F), whereas the UD carbon fibres are used as reinforcements.

Discussion

The model accurately describes the damaging mechanism of composite specimens investigated in (Park et al. 2010). Moreover, it can accurately predict the regain of stiffness, i.e. the matrix material elasticity modulus, during the healing periods. Further research is focused on the implementation of the developed model into the VUMAT user material subroutine used in Abaqus/Explicit. The goal is to use the developed numerical methodology for simulation of healing in structures damaged during the hail- or bird-strike damage, or during a ballistic impact.

Acknowledgments

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Keywords

FEM micromechanical model of intrinsic self-healing, self-healing unidirectional composites, con-tinuum damage healing mechanics, rule of mixtures

Development of Photocatalytic Nanocomposite Based on Titanium Dioxide and Reduced Graphene Oxide

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Introduction

In recent decades, due to the growth of the industries, the aquatic ecosystem is contaminated by pollutants including harmful and persistent dyes. The usage of dyes agents in many industries leads to the global problem because of their non-degradable properties. Since conventional water treatment plants are usually unproductive in removal dyes from effluents, more efficient technologies, advanced oxidation processes (AOPs) as well as heterogeneous photocatalysis based on TiO_2, are used. The major drawbacks of TiO_2 photocatalyst are fast recombination of photogenerated electron-hole pairs, which leads to lower photocatalytic activity (limited activity in the visible light range) under solar irradiation. Hence, modification of TiO_2 photocatalyst with materials such as non-metals, metals, or graphene-based materials like reduced graphene oxide (rGO) is commonly an approach that has been used to overcome their limitations. To use a visible range of the solar spectrum and efficient removal of organic compounds, it is necessary to produce competent TiO_2/rGO nanocomposites for the degradation of dyes from an aqueous medium.

Methods

GO is synthesized by Hummer's method using natural graphite flakes (≤50 μm). TiO_2 colloidal sol, titanium isopropoxide as titanium precursor, is prepared using followed components: TTIP:PrOH:AcAc:HN at a molar ratio 1:35:0.63:0.015. The TiO_2/rGO nanocomposite is also synthesized by the hydrothermal procedure followed by calcination treatment. The optimal amount of reduced graphene oxide in the nanocomposites is evaluated. The properties of the prepared photocatalysts are analysed by several characterization techniques including FTIR, Raman spectroscopy, XRD, UV-Vis DRS spectroscopy, XPS, and SEM/EDS. The photocatalytic activity of nanocomposites is monitored through the degradation of Methylene blue (MB) dye in an aqueous medium under UV and simulated solar irradiation. At the same time, photocatalytic parameters such as concentration of MB dye solution and amount of prepared photocatalyst are evaluated.

Preliminary results

The obtained preliminary results show successful synthesis of GO material and nanocomposites based on TiO_2/rGO according to carried out characterization analysis of the synthesized materials. The results show a strong impact of the amount of the rGO in the prepared nanocomposites which are closely related to properties as well as photocatalytic activity.

Discussion

The developed nanocomposite photocatalysts are able to be used as a highly efficient photocatalyst for the removal of many harmful organic pollutants from wastewater. Structural, optical, and morphological properties depend on the amount of rGO in the prepared nanocomposites as well as photocatalytic degradation of MB dye in an aqueous medium using UV and simulated solar irradiation.

Keywordds

GO, TiO2/rGO nanocomposite, simulated solar irradiation, dye, wastewater treatment

Design Parameters of Heart Pump

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Introduction

In this paper, design parameters of new bladeless centrifugal heart pump are presented. The application of pump as heart pump imposes design limitations on the geometry of the heart pump. Research and development of heart pump is focused on achieving heart pump performance and hemocompatibility i.e., the amount of mechanical damage caused by a pump on blood cells. Main prediction parameter of pump hemocompatibility is wall shear stress, stagnation, and recirculation zones. The bladeless centrifugal heart pump creates less shear stress, as the flow is created due to adhesive and cohesive forces, without impact of blood cells on rigid blade surfaces resulting in greater hemocompatibility.

Methods

Research of pump properties is based on applying turbomachinery principles and fluid dynamics theory on the differential volume of the fluid between two discs. Design parameters of the heart pump are derived from continuity and Navier – Stokes equation. Furthermore, dimensionless parameters of heart pump are defined with dimensional analysis. $\Delta p - Q$ characteristic curve of referent heart pump Heart Mate II is experimentally measured, as starting point for values of design parameters for new heart pump design. Heart Mate II is selected as referent pump based on more than 10 years of clinical data and implementation. Experimental setup is open loop mock circulatory system developed in Laboratory for Artificial Cardiovascular Circulation, Faculty of Mechanical Engineering and Naval Architecture.

Preliminary results

Expressions for pump head and flow, wall shear stress, momentum and power are shown. Dimensionless parameters are defined: Reynolds number, two dimensionless geometric parameters, and dimensionless wall shear stress parameter. Essential criteria in heart pump development are pump head and flow, and wall shear stress. Second important factors are minimal volume of heart pump and power consumption. Values of design parameters internal and external disc diameter (R_1, R_2), distance of discs (h), number of discs (m) and angular velocity (ω) are defined with respect to essential criteria. The diagram of $\Delta p - Q$ characteristic curve for design parameters of new bladeless centrifugal heart pump and Heart Mate II are presented.

Discussion

The aim of this study was to analytically derive de-sign parameters of new bladeless centrifugal heart pump and define their value. The steeper $\Delta p - Q$ characteristic curve for new heart pump indicate that the new heart pump is expected to have slower speed to achieve same flow. Slover speeds indicate lower wall shear stresses thus allowing acceptable hemocompatibility. Further numerical and experi-mental research of new pump design is required.

Acknowledgments

The research is supported by Competitive funds "Experimental research" of Faculty of Mechanical Engineering and Naval Architecture.

Keywords

Heart pump, design parameters, mock circulatory system

Development of Criteria for Selection of Batch Distillation Operation Mode

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Introduction

Batch distillation is a flexible and energy intensive process often favoured for small-scale separations of liquid mixtures. Process flexibility allows utilization of existing equipment for a variety of separations, at the cost of relatively low separation efficiencies and difficulties in modelling and optimal process operation. Although numerous modes of process control are described in literature, constant reflux ratio mode, which is often suboptimal, is applied routinely. The goal of this work is to develop criteria for selection of improved batch distillation operation mode for a variety of mixture, product and equipment parameters.

Methods

Indirect iterative gradient algorithm for optimal control is employed on a process model to find optimal trajectory of reflux ratio which minimizes one of the suitable goal functions. So far, energy minimization for set amount of product and product maximization in set time, both in combination with endpoint constraint of average product composition, have been considered as goal functions. For practical purposes of large-scale optimizations and implementation possibilities, optimal profile obtained by gradient algorithm is approximated with a similar profile having substantially fewer degrees of freedom. Approximate reflux ratio profile is then optimized for a wide variety of process parameters. Based on these results, criteria for improved process control are defined as a function of analyzed parameters. Process model and selected optimization results are experimentally validated.

Preliminary results

Simulation case study was conducted for batch distillation of ethanol-water mixture. It was shown that significant time and energy savings of up to 25 % can be achieved by using optimal variable reflux ratio compared to the conventional constant reflux ratio profile. Total reflux ratio is optimal start-up phase in all analysed cases, but transition to production phase occurs before steady state composition is achieved. Depending on process parameters, simplest profiles to approximate optimal reflux ratio profile sufficiently well are total reflux ratio followed by constant, piecewise constant or profile linear in time.

Discussion

Conducted simulations show that process performance can be improved by using simplified reflux ratio profiles. Structure of improved profile depends upon parameters such as initial compositions, tray number and holdups, which affect difficulty of separation. By simultaneous optimisation of start-up and production phase, additional savings can be achieved compared to the optimisation of production phase with steady state composition set as initial condition, which is the predominant case in literature. Although results seem promising, experimental validation is required to confirm conclusions. Analysis of wider parameter space and experimental validation are next steps of this work.

Keywordds

batch distillation, reflux ratio, optimal control, start-up, ethanol-water

Calibration of a Real Time Cycle SI Engine Simulation Model in the Entire Engine Operating Map

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Introduction

The rapid increase in computational power of modern computers enabled the use of numerical simulations in variety of applications during the internal combustion engine development process. Depending on the desired application, simulation models of different fidelity can be applied. Compared to the experimental results, detailed 3-D CFD models offer the most accurate results, but are also time consuming and therefore inconvenient for extensive analysis of various operating parameters that affect the engine operation. In such cases the so-called cycle-simulation models, based on 1-D/0-D approach, can be very helpful by offering a good compromise between computational effort and accuracy of the simulation results. In recent years, such models are more and more intended to be real-time capable to enable their application in Hardware-in-the-Loop simulations. Therefore, the challenge is to find the optimal balance between predictability and calculation speed of the model.

Methods

In this study, a 0-D modelling approach is presented and used to investigate its potential for real-time simulation applications. The calibration method that results with a real-time capable simulation model of the complete engine system with good predictability across the entire engine operating map is defined. The procedure includes calibration of both gas exchange and combustion model constants with the help of Proportional Integral controllers for each of the experimentally investigated operating points, and afterwards the parametrization of the selected constants based on the calibration results.

Preliminary results

The validation of characteristic combustion phases shows a significant improvement in combustion process prediction after calibration and parametrization of the model constants, which consequently reduces the average error in transient results by approx. 2-3 times compared to the simulation model with default parameters. Average error in calculated air mass flow for default model of approx. 9 % was reduced to 3 % for parametrized model. Similar result is achieved in calculated IMEP, where the average error was reduced from 10 % to 4.5 %. As expected, the average error in calculated ISFC is lower for both cases, being 8 % and 3.3 % respectively. The overall accuracy of the final simulation results, compared to the experimental results, is above 95 %.

Discussion

The results confirm that a good predictability of the real-time capable model can be achieved with only a small number of experimentally investigated operating points required for calibration. The use of PI controllers for the automatic calibration of the model parameters significantly reduces user effort and speeds up the calibration process. Identification of model parameters and control values for calibration is a crucial part of this method. However, general guidelines presented in this study can be applied to different engines and are not limited to the combustion model used in this study.

Keywordds

IC Engine, Calibration, Real Time Simulation, Spark Ignited, Combustion.

Synergistic Effect and Prediction of Product Yield from Biomass-Plastic Co-Pyrolysis

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Introduction

Decarbonisation of the high-energy intensive processes often requires the utilisation of various alternative fuels since electrification might not be a possible or economically viable option. Lately, co-pyrolysis of biomass with waste plastic is introduced as a promising solution to enhance the properties of conventional biofuels, simultaneously dealing with a waste management problem. During the co-pyrolysis interaction between feedstock promotes the synergistic effect, responsible for the distribution of obtained products. The influence of feedstock selection is significant since it greatly determines the process output and product quality. Besides the type of used feedstock, the mixing ratio strongly influences achieved synergy and the process dynamic inside the reactor. This work aims to investigate the acceptable share of plastic content inside the mixture to enhance biofuel properties. In addition, in the scope of the work, various kinetic and thermodynamic methods will be used to provide support to experimental results and develop a methodology that could be used as a preliminary assessment for product yield and distribution.

Methods

The experimental part of the investigation consists of pyrolysis and thermogravimetric analysis (TGA) coupled with mass spectrometry and gas chromatography to analyse the obtained products, which are later used to assess the fuel quality. In addition, kinetic and thermodynamic analysis is carried out to give a comprehensive insight into process dynamics. The main part of the work will be focused on developing correlations between initial feedstock parameters and final product distribution to establish a methodology for the prediction of product yield.

Preliminary results

Up to now, several experimental investigations have been carried out on a sawdust mixture of fir, beech, and oak wood with polystyrene and polyurethane foam. Part of the analysis was dedicated to investigating the composition of obtained bio-oils and syngas to evaluate their potential for fuel application. Results show that plastics' introduction can greatly improve the biofuel properties, especially when the share does not exceed 50 % of the fuel blend. Moreover, it was shown that small addition of plastics could reduce the activation energy of the process while further increase results with the increment of activation energy, as well as the other observed thermodynamic parameters.

Discussion

Based on the experimental results, preliminary work was done to establish a correlation for product yield prediction. It was shown that it is possible to predict the yield of solid fraction with high correspondence to experimental results. Nevertheless, in the case of volatile fractions, it was shown that additional efforts should be put to understand the mechanism responsible for product distribution to predict the yield of liquid and gaseous fractions accurately.

Keywordds

co-pyrolysis, biomass, waste plastic, bio-oil, synergistic effect

Laser Beam Surface Modification for the Deposition of Thin Hard Coatings

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Introduction

Titanium and its alloys, due to their good characteristics, are increasingly used in industry. To improve the tribological properties of Ti-alloys in order to extend the service life and increase productivity, the use of vapur phase coating processes is increasing. The surface preparation of the base material has a significant impact on the adhesion of the coating in order to obtain a uniform roughness profile that will reduce the possibility of delamination of the coating. By applying the surface modification with a laser beam, it is expected to achieve a roughness profile that will improve the adhesion and mechanical and tribological properties of coatings in relation to conventionally prepared surfaces. The obtained properties of Ti-6Al-4V alloys depend on the used parameters such as laser power P [mW], scanning speed v [mm s^{-1}], and layers passed.

Methods

Before laser treatment, Ti-6Al-4V samples were mechanically polished with sandpaper and diamond pastes. In the next phase, the surfaces were treated using a SpectraPhysics Spitfire femtosecond laser seeded by Tsunami. The laser parameters were varied to create different laser textures on the surface with various parameters: laser power, scanning speed, layers passing, and laser passage procedure. The prepared sample surfaces were coated with titanium nitride (TiN) by the physical vapor deposition process – PVD. SEM analysis of microstructure. The surface topography was determined by SEM analysis and the roughness profiles of the samples were measured.

Preliminary results

Preliminary investigations were performed on samples of titanium alloy Ti-6Al-4V and the roughness profiles were analyzed for applying thin hard coatings by PVD process. Measurements of the surface roughness profile of the tested samples after laser treatment were ranged from Ra 0.035 μm to 0.045 μm and showed a more uniform roughness profile. The obtained roughness values and the appearance of the surface profile lead to the conclusion that by changing the parameters of the power and speed of the laser beam, it is possible to obtain uniform roughness parameters in order to achieve better adhesion of the coatings.

Discussion

According to the SEM analysis, changes were noticed in the surface after laser processing. It can be observed that at lower scanning speeds and one-pass laser radiation there are no clear visible traces of laser beam. The roughness profile of all laser-treated samples has a different profile geometry compared to the reference sample. From this, it can be concluded that the laser parameters influence on the topography and roughness profile of the surface.

Keywords

Ti-6Al-4V alloy, surface roughness, adhesion, topog-raphy

Implementing the Demand Response in the Smart Islands Archipelago

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Introduction

Increased penetration of renewable energy sources is accelerating the decarbonisation of the energy systems. On the other hand, a large share of variable renewable energy sources can cause uncertainties in the energy systems that lead to larger fluctuations of the electricity price on the market. Advanced information and communication technology make it possible to exploit these fluctuations by including the citizens in the electricity market. This is in line with the current European Union legislation which created new legal frameworks for increased citizens participation in the electricity market.

Methods

Thus, this paper proposed a novel demand response model based on the price differentials of consecutive electricity market prices. The model is implemented in the detailed electric distribution grid with all necessary grid constraints. The case study was conducted on islands in the Kvarner archipelago in Croatia. Islands are areas characterised by harsher conditions than those on the mainland where the fuel prices are higher, infrastructure is more expensive and weather conditions often cause problems in the operation of the electricity, water and transport sector. Thus, the successful implementation of advanced technology on the islands would be more easily implemented and transferred on the mainland. The proposed demand response model can be implemented by adjusting the demands of the heating, transport or water sector of residential buildings as well as other industry or tourist facilities.

Preliminary results

The results of the case study showed that implementation of the demand response model resulted in 258.7 € savings for one day when the highest flexibility was allowed. The results also showed that voltage change in the grid did not change for more than 0.13 kV, thus the grid code was not violated.

Discussion

From the obtained results, it can be concluded that implementation of the demand response model and inclusion of the citizens in the energy markets results with benefit for all stakeholders.

Keywordds

Energy planning, Renewable energy sources, Demand reponse, Distribution grid, Cross-sector integration

Repeatability and Reproducibility in the Field of Atomic Force Microscopy in Dimensional Nanometrology

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Introduction

In the field of dimensional nanometrology, the paper estimates the component of measurement uncertainty due to the impact of repeatability and reproducibility of measurement results. According to the Guide to the expression of uncertainty in measurement (GUM), measurement uncertainty is a parameter associated with the result of a measurement that describes the dispersion of the values that could reasonably be attributed to the measurand with a given probability. Repeatability of measurement results is a close agreement of results of consecutive measurements of the same measured quantity performed in the same measurement conditions (same operator, same measurement method, same measuring instrument, same environmental conditions, short period of time). The reproducibility of measurement results is a close agreement of the measurement results of the same measured quantity, but performed under changed measurement conditions. The type A measurement uncertainty component was estimated for the measurement results of areal topography parameters.

Methods

The analysis of repeatability and reproducibility of the results was performed by measuring nine samples. The samples are stainless steel plates measuring 20 mm × 20 mm × 5 mm. On each sample, measurements were performed at three measuring points, and the measurements were repeated five times. The measurements were performed using an atomic force microscope (AFM), where the repeatability and reproducibility of the measurement results of the surface topography parameters Sq, Ssk, Sku, Sp, Sv, Sz and Sa were analyzed. Based on the measurement results obtained in the conditions of repeatability and reproducibility, the type A measurement uncertainty component for the stated areal topography parameters was estimated.

Preliminary results

The standard deviation of the repeatability of an individual topography parameter for the same measuring point is a maximum of 1 nm. In order to determine the standard deviation of reproducibility, measurements were performed by two operators at five measuring points over a longer period of time. The measurement results were processed using the method of analysis of variance (ANOVA). The results of the analysis showed that changing the measuring point on the sample leads to a statistically significant difference between the measurement results while there is no statistically significant difference between the measurement results of different operaters (level of test significance α = 5 %). The type A standard uncertainty, due to the influence of repeatability and reproducibility of measurement results, was estimated from the pooled standard deviation s_p, in accordance with the GUM.

Discussion

The procedure for estimating the component of measurement uncertainty due to the influence of repeatability and reproducibility of measurement results obtained using an atomic force microscope is presented. In order to estimate the measurement uncertainty of the measurement results, it is necessary to assess the other components of the measurement uncertainty of the measurement results. Given the complexity of the AFM measurement system, it is necessary to investigate how and to what extent a particular parameter affects the measurement process and result.

Keywordds

atomic force microscope, dimensional nanometrology, repeatability and reproducibility, measurement uncertainty

Reduced-Order Homogenization of Ductile Heterogeneous Materials

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Introduction

Ductile heterogeneous materials of complex microstructure are an inevitable part of modern engineering structures, and their multiscale nature represents a major obstacle in their numerical modeling. Since the classical continuum mechanics characterizes average material behavior, i.e. does not take into account contributions of individual micro-constituents, the last few decades have been characterized by the intense development of multiscale methods. Although they proved themselves to be a powerful tool in the field of numerical modeling of ductile heterogeneous materials the use of these methods often leads to high computational costs and long computational time. In this work, a reduced-order, data-driven, two-scale approach for predicting the behavior of ductile heterogeneous materials, in a computationally efficient way, is presented.

Methods

The reduction in total computational cost is accomplished through two innovations: (1) the use of data compression algorithm k-means clustering; and (2) a new method called the self-consistent clustering analysis. The first innovation allows for a significant reduction in the number of degrees of freedom. This is accomplished by discretizing the complex microstructure of a ductile heterogeneous material into a relatively small number of clusters, i.e. sub-areas in which the stress and strain values are constant. On the other hand, self-consistent clustering analysis represents a numerical procedure for solving the boundary value problem, which is described by the Lippmann-Schwinger equation. The efficiency and computational speed of a presented method are demonstrated on several numerical examples.

Preliminary results

In an analysis of a 2D microstructure of a ductile heterogenous material subjected to tension and shear, under small strains assumptions, two major goals have been achieved: good agreement with the results obtained by Direct Numerical Simulation (DNS) and a reduction in computational time of several orders of magnitude.

Discussion

The aim of this research is to develop an efficient two-scale computational approach for multiscale analysis of ductile heterogeneous materials at small strains and without the occurrence of damage. By using the reduced-order homogenization method, the process of homogenization of a microstructure can be greatly accelerated. Our ultimate goal is to extend the presented algorithm to model damage of ductile heterogeneous materials at finite strains.

Keywordds

Ductile heterogeneous materials, Multiscale methods, Reduced-order homogenization, k-means clustering, Lippmann-Schwinger equation

The Influence of Measuring Objects and Software on the Measurement Results of Optical 3D Measuring Systems

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Introduction

Measuring devices these days must be able to measure objects of complex geometry and must be accurate, fast and economical. Optical 3D scanning technologies are potential measuring systems that can meet the required requirements. Measurement with these systems has advantages over other measurement methods. Optical 3D measuring systems have simple procedure, high density of data, possibility of integrated reverse engineering and inspection, independence of results on rigidity of object. This paper will investigate the influencing factors that occur in 3D measurements with optical scanners, and the results of the research will be used in the assessment of measurement uncertainty in future research.

Methods

Two groups of influencing factors on the measurement results are included in this study. These are the impact of the measurement object and the impact of the software. Two influential factors related to the object of measurement, spray coating and roughness, and two factors related to the influence of software, polygonization and interpolation, were considered. In this research, two measuring objects of equal dimensions but different surface roughness were used. In order to reduce the influence of the optical properties of the material, a coating is applied to the surface of the object. Helling spray coating was used in two ways. One of the approach was spray deposition using bottle, and the second method was using spray gun. A full factorial design of experiment (DOE) was used in the design of the experimental plan. The process of 3D digitization was performed with the ATOS Core 3D optical measuring system. Data processing after each measurement was performed using ATOS inspection software. The measurement results were processed by the methods Analysis of variance ANOVA and by the method of linear regression.

Preliminary results

The results of the ANOVA analysis and the results of the regression analysis have a p-value of the model less than 0.05, which shows the significance of model. The results differ in determining the influencing factors. Interpolation is a significant factor in ANOVA analysis, while it is not significant in regression analysis. Since some results deviate from the direction obtained by the relationship between the predicted and actual response in the regression analysis, it can be said that the more credible results are results of the ANOVA analysis.

Discussion

The results of the research provide a better understanding of the factors that influence measurement results. With respect to the obtained results, evaluation of measurement uncertainty for 3D optical measuring systems should take into account influence of objects surface roughness, spray coating and method of interpolation. Further steps in investigation should include research of other influence factors that were not considered here. Also, the research should cover the determination of the capabilities of 3D optical measurement system in comparison with other 3D measurement systems.

Keywordds

3D scanning, optical measuring systems, measurement uncertainty

A Numerical Method for Material Characterization of Hyperelastic Materials from a Biaxial Experiment with Cruciform Samples

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Introduction

Mechanical properties derived from experiments are essential for precise and reliable numerical simulations in product development. Anisotropic hyperelastic materials such as soft tissue, 3D printed polymers or composites have to be subjected to multiaxial stress states to adequately determine their mechanical properties. The most common procedure is a planar biaxial tensile test with different load ratios. Usually, material parameters are derived from experimental force-stretch data with the least squares method by comparing experimental and modelled stresses. During the experimental procedure, the force is measured while the stress is approximated based on an assumption of a homogenous stress field. It is a straightforward procedure when a simple quadratic specimen is used. But, in the case of cruciform samples, the stress field is heterogeneous and, the load-carrying surface is not unambiguously defined which leads to incorrect experimental stresses and poor material characterization. Thus, there is a pressing need to develop a new procedure that could be used for non-standard specimens.

Methods

The planar biaxial tensile experiment of the cruciform sample are iteratively simulated and results are compared with experimental results to determine residual. In stead of classical least square method two new approaches are suggested. The first method is based on a minimum of a residual calculated under displacement – force curve. In the second approach the residual is computed as the difference between modelled and experimental strain energy. Newton – Raphson method is applied to minimize residuals and to determine material parameters for each subsequent iteration.

Preliminary results

Preliminary results of a new method so far showed improved material parameters estimation in comparison with least squares method. To ensure verification and convergence of a method, it was first applied to numerically simulated experiments. The simplest cases with same constitutive models of experiment and simulation turned out to have nearly ideal correlation. Furthermore, verification of a method was tested for cases with different strain energy functions with substantially improved results.

Discussion

Although a new numerical method is computationally expensive when compared with least squares method, obtained material parameters are more accurate. Both residual definitions have their weaknesses and strengths. First method based on a residual calculated under displacement – force curve converges faster than strain energy approach. On the other hand strain energy approach is more precise even though it requires higher computational time. The future work will be based on reducing computational costs of the method by testing various minimum searching algorithms.

Acknowledgments

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Keywords

hyperelasticity, cruciform sample, biaxial experiment, Newton-Raphson method

Optimization of Flapping Wing Dynamics for Martian Atmosphere via DMOC Approach

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Introduction

NASA's Ingenuity Mars Helicopter has recently performed the first powered controlled flight on another planet. However, in spite of success of this mission, rotary wing solution might not be the optimal technology for flying in thin Martian atmosphere. The low density of the atmosphere (only 1% of the Earth's) forces the aircraft to fly at low Re numbers, which significantly deteriorates the performance of a rotary wing. On the other hand, insects fly very efficiently at the same Reynolds numbers, with great aerial capabilities, which makes the insect-type aircraft a promising concept for Mars exploration. To this end, the novel optimization algorithm for development of insect-type aerial vehicle, capable of flight in Martian atmosphere, is proposed.

Methods

The novel optimization algorithm combines Discrete Mechanics and Optimal Control (DMOC) approach with quasi-steady aerodynamical model. DMOC is a direct transcription method, for optimal control problems in mechanics, in which discretization of the Lagrange-d'Alembert principle results in the time stepping equations that are implemented as equality constraints in the constrained nonlinear optimization problem. On the other hand, the basic assumption of the quasi-steady aerodynamic model is that the aerodynamic forces are inherently time independent which means that the aerodynamic forces directly depend only on kinematic variables. This simplification, combined with adequate experimental data, results in the aerodynamical model with a good ratio of accuracy and computational efficiency. The flapping-wing vehicle is modeled as a system of three rigid bodies based on the morphological characteristics of the fruit fly (lat. Drosophila melanogaster). The goal of optimization is to minimize energy consumption, that is to find the most efficient flapping pattern for hovering in the Martian atmosphere.

Preliminary results

The optimal combination for hovering on Mars is found for wings uniformly scaled by scaling factor n = 4.2 while flying in the conditions resulting in mean Reynolds number Re = 631. The algorithm also found different energy-efficient flapping patterns for a wide range of scaling factors, thus providing new insights into the physics of flapping flight on Mars and valuable directions for the design of Mars flapping wing aerial vehicles.

Discussion

Results of the numerical experiment indicate that the developed optimization algorithm can be successfully used for computationally efficient optimization of design and dynamics of an insect-type flapping aerial vehicle for Mars exploration purposes — where higher fidelity fluid-structure coupled procedures fail to deliver because of computational non-efficiency. The next natural step, in the development process of the presented algorithm, is to expand the existing aerodynamic model with forward flight features.

Acknowledgments

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Keywords

Flapping wing, Mars exploration, Discrete mechanics and optimal control

The Risk of Rupture and Abdominal Aortic Aneurysm Morphology

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Introduction

Prediction of rupture and optimal timing for abdominal aortic aneurysm (AAA) surgical intervention remain wanting even after decades of clinical, histological, and numerical research. Rupture prediction continues to be based primarily on the maximum diameter and clinicians' experience. However, it is obvious that for patients with different build (e.g., height, body mass index), race and sex, critical AAA maximal diameter will vary, and the treatment decision cannot be made based solely on one geometrical feature. Therefore, the new parameter that could help predict AAA rupture more reliably is needed, and it should be based on multiple geometrical indices. Numerical models could prove to be very helpful when defining the new, more reliable rupture prediction index.

Methods

Growth and remodelling (G&R) model used in this research has been implemented into finite element code. Numerical simulations with 96 combinations of input parameters were run and, in total, 646 follow-ups were conducted in order to cover as much of the real world scenarios (i.e., differences between patient sex, smokers and non-smokers). Using the simulated results, geometrical parameter that could predict the AAA rupture for overall population better than currently used criteria was defined. It is desirable for this parameter to have the small scattering area and linear behaviour.

Preliminary results

It is necessary to find the relationship between the estimated likelihood of rapture and size index for every geometrical parameter. Additionally, correlation coefficient is calculated for every parameter to determine which parameter predicts the likelihood of rupture the best. Likelihood of rupture of some observed geometrical indices is clearly grouped depending on the healthy diameter, so they are not good predictors themselves. Newly introduced parameter tends to eliminate the mentioned disadvantage and has great correlation coefficient

Discussion

AAA rupture is difficult to predict. Currently used parameters do not provide sufficient information and cannot be reliably used on the overall population. Numerical analyses give us the chance to examine many different possibilities and find the geometrical parameters that will be able to predict whether the rupture will occur. It could be used by clinicians, regardless of patients' build, race or sex. Additionally, parameters can be computed easily, without tedious processing of CT images.

Acknowledgments

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Keywords

Abdominal aortic aneurysm, Finite element analysis, Growth and remodeling, Rupture

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