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100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET

UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

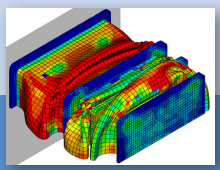
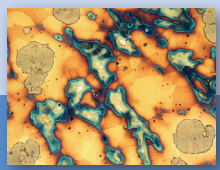
Sixth Annual PhD Workshop

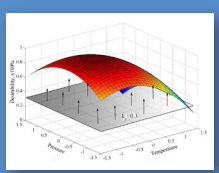
PhD Study of Mechanical Engineering, Naval Architecture, Aeronautical Engineering and Metallurgical Engineering

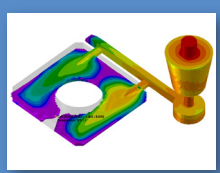
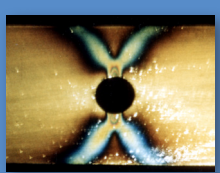
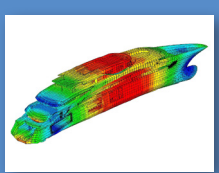
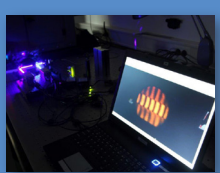
Book of Abstracts

July 6, 2020



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SISAK

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Preface

This booklet contains abstracts presented at the 6th Annual PhD Workshop, which took place on July 6, 2020. 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.

34 participants on the PhD workshop presented preliminary topics of their theses, while 16 participants presented final PhD topics. 47 workshop participants are from Croatia, while 3 are from foreign countries (1 from Bosnia and Herzegovina and 2 from Kosovo). Contributions collected in the booklet of abstracts are from different modules of the PhD study: Process and Energy Engineering (13 contributions), Computational Mechanics (3), Theory of Structures (3), Mechatronics and Robotics (6), Industrial Engineering and Management (1), Scientific Metrology in Mechanical Engineering (4), Aeronautical Engineering (3), Materials Engineering (9), Advanced Production Technologies (2), Naval Architecture and Ocean Engineering (4) and Metallurgical Engineering (2). Diversity of these topics clearly indicates broad and rich research interests and activities at the Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy.

Editors

Contents

TOPIC NOT APPROVED

Numerical Model of a Self-Healing Fibre Reinforced Composite Material

PhD candidate: Dominik Brezetić
Mentor/s: Ivica Smojver
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

This research deals with development and numerical implementation of a constitutive model for a composite material with the ability to heal matrix micro-damage. Self-healing materials are already known for some time, e.g. in (Barbero et al. 2005) a constitutive model of a self-healing composite material with extrinsic self-healing ability is proposed, i.e. healing occurs due to the rupture of microcapsules which contain the healing agent. The constitutive model proposed in this work is a novelty in the field of continuum damage healing mechanics (CDHM), since it exhibits intrinsic self-healing ability of a composite material.

Aims

The idea is to use this model to evaluate applicability of self-healing materials in cases where damage poses a problem in the exploitation of aircraft structures. Common examples of damage occurrence are BVID (Barely Visible Impact Damage) and delamination.

Methods

Intrinsic self-healing ability means that healing is initiated by external stimulus, here it is heat, and it is time-dependant. Damage and healing evolution functions are scalar, after (Darabi et al. 2011) and (Abu Al-Rub et al. 2010), respectively. Three material configurations: effective, healing and nominal are taken from (Darabi et al. 2012). Stress, strain and tangent stiffness tensors are transformed from one configuration to another by means of strain equivalence hypothesis, a well-known transformation hypothesis in continuum damage mechanics. Thus, numerical implementation becomes relatively straightforward. Parameters of those evolution laws are adjusted to describe the behaviour of the matrix material. In this early phase of the research, an advanced ethylene/methacrylic acid (E/MAA) copolymer, DuPont™ Surlyn® 8940 thermoplastic resin, is used as matrix material, while unidirectional carbon fibres are used as reinforcement. Surlyn® 8940 is also used as a means for validation of the proposed constitutive model, since the model describes damage and healing effects in the matrix material only. On the other hand, reinforcing fibres are modelled as linearly orthotropic elastic material. The self-healing property of Surlyn® 8940 is already proven, e.g. in (Wang et al. 2012), where double cantilever beam (DCB) test is performed. Usage of Surlyn® 8940 in the form of rectangular patches between unidirectional carbon prepregs resulted in increased fracture toughness after the healing process. Constitutive model was implemented into Abaqus user subroutines UMAT and VUMAT and validated by means of simple static test cases and loading/unloading cycles.

Expected scientific contribution

The proposed methodology, validated with experimental measurements, enables accurate constitutive modelling of composite structures with self-healing ability using the aforementioned damage and healing evolution functions.

Acknowledgments

The research is funded by the Croatian Science Foundation (HRZZ) in the framework of the project ACCESS (AdvanCed CompositE Self-healing Simulation) (IP-HRZZ-2018-01-2248).

Keywords

micro-damage, intrinsic healing, self-healing composites, continuum damage healing mechanics

The Finite State Method in the Ship Production Process Engineering: Serial Lines

PhD candidate: Viktor Ložar
Mentor/s: Neven Hadžić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Shipbuilding production is a complex production system involving different materials, technologies, and disciplines. This complex combination makes it difficult to find a suitable approach for designing the production process. Every shipyard has multiple ways to organize their workshops and to predict cost and time schedules. However, it is well known that it is very hard to produce the ship on time and with the optimal use of resources. For designing such complex systems analytical, semi-analytical, or numerical methods can be used. Today the semi-analytical and numerical methods are used in a wide range of mass production while the analytical approach has limited utility. The shipbuilding industry, especially in Croatia, uses such methods in a very limited scope. The analytical approach was founded by Sevast'yanov in 1962 for a single machine line with two buffers. For more buffers and machines the problem gets too complex and was solved recently. The semi-analytical approach aggregates the whole line to a single machine line and was verified with numerical methods. Numerical methods need a lot of data to predict the parameters of interest.

Aims

This doctoral thesis' main target is developing the finite state method. This is a problem that hasn't been solved even 56 years after the first time the Markov chain was used for a single machine line. The new method is going to be verified by several measurements in the industry. The next step will be the comparison of the established semi-analytical approaches with the new finite state method. Another step will be the development of a method of numerical modeling which would make it easier to predict the production costs and impact on the environment.

Methods

Several methods will be used for reaching the aims, like: division, generalization, analysis, synthesis, specifications, deduction, and collection of data. The division will be used during the formulation of the analytical solution. The transition matrix will be reduced from a complex problem to several simpler problems. These results will be generalized for an arbitrary number of machines and buffers. The analysis of the steady and transient response will be based on the solution of the eigenvalue problem. The synthesis will be used during the consideration of bottlenecks and lean production. The specification method will be used to create a model for production costs. Using the deduction method a model for energy consumption will be created. The collection of data during four measuring campaigns will be performed using a questionnaire and interviews to find out the buffer capacity, costs of production, and energy consumption.

Expected scientific contribution

The main scientific contribution will be solving the problem of the application of the analytical approach of production lines, the development of the finite state method and the implementation of program code. The semi-analytical approach will be validated by using the analytical approach and the collected data. The research results will be published in international journals, at international conferences and will be applicable in the shipbuilding industry.

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

Shipbuilding, production process engineering, Ber-noulli lines, finite state method

Energy Efficiency and Environmental Eligibility of Short Sea and Inland Waterway Vessels

PhD candidate: Maja Perčić
Mentor/s: Nikola Vladimir
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Exhaust gases released due to combustion of fossil fuel in ship engines negatively affect both humans and environment. With UN's stance that all industries must make a proportionate contribution to reducing GHG emissions, International Maritime Organization (IMO) has set a goal for reducing 70% of carbon dioxide (CO_2) from international shipping by the end of 2050. In order to achieve this goal, a set of technical and operational measures has to be implemented. Within technical measures, replacing conventional marine fuel and power system with alternatives are of the great interest in order to comply with the emissions regulation. Application of alternative power system configurations depends on specific area of navigation, cost-effectiveness and environmental friendliness of the solutions.

Aims

The aims of this research are to define the energy efficiency design index (EEDI) for short sea and inland waterway vessels applicable to ship power systems with alternative energy sources, to investigate the availability of alternative energy solutions in Croatia and their applicability in the Croatian short sea and inland waterway fleets and to develop a design procedure for ship power systems with high energy efficiency, taking into account the specific exploitation requirements of short sea shipping and inland waterway navigation and market regulations in Croatia.

Methods

Selected alternative power system configurations which have more favourable energy efficiency design index values over existing solutions, are investigated from an environmental and economical point of view. Environmental impact of different power system configurations is assessed by performing the Life-cycle assessment (LCA) by means of software GREET 2019. Economic analysis was conducted by performing Life Cycle Cost Assessment (LCCA) which involves possible implementation of carbon allowance in shipping. These results are illustrated on Croatian short sea shipping and inland navigation fleets and results of each configuration are compared in order to setup the optimal configuration for particular ship.

Expected scientific contribution

This research will result with the energy efficiency design index of short sea and inland waterway vessels in Croatia with a high share of alternative energy sources, set of alternative energy solutions applicable in the Croatian short sea and inland waterway sectors and design procedure of high energy efficiency power systems for ships that frequently change operating modes, which are predominately present in Croatian short sea and inland waterway fleet.

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). Miss Maja Perčić, Ph.D. student is supported through the „Young researchers' career development project – training of doctoral students" of the Croatian Science Foundation, funded by the European Union from the European Social Fund.

Keywords

Short sea shipping, inland navigation, LCA, LCCA, alternative ship power system

Development of New Methods and Devices for Improvement of Thermocouple Measurement Accuracy

PhD candidate: Ivan Matas
Mentor/s: Lovorka Grgec Bermanec
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Thermocouple is the most frequently used temperature sensing element. Many industrial processes, such as energy or food production, rely on accurate thermocouple measurement. Measurement performance of a thermocouple depends critically upon uniformity of physical and chemical properties along its length. Those properties have tendency to change during thermocouple's lifetime, as a result to heat or chemical exposure or mechanical damage. In order to assure accurate low uncertainty temperature measurements, it is necessary to monitor drift and inhomogeneity as main indicators of thermocouple's performance. Present techniques for determination of those indicators are not standardized nor easy-to-use, as well as time-consuming which drives the research of new methods and devices, that will offer benefit both to industry and laboratories. Also, more accurate temperature measurement leads to increased efficiency of industrial processes and contributes to optimal use of energy and resources.

Aims

The aim of this research is the development of novel methods and devices for verification of thermocouple performance, which will increase confidence in thermocouple measurement and reduce temperature measurement uncertainty.

Methods

In the scope of this research, a novel device for monitoring drift of thermocouple will be constructed and tested. Different designs and measurement devices will be combined with thermocouple, to get the best solution for monitoring the change of voltage generated by thermocouple (drift) without stopping the production process. That will help industry with maintenance and replacement decisions. At the level of primary and secondary laboratories, inhomogeneity of thermocouple wire, will be further researched. Constant exposure to harsh environment or mechanical damage, can affect the homogeneity of thermocouple wire, causing measurement error. By developing a new standardized method for identification and quantification of influence of inhomogeneity on temperature measurement, uncertainty of thermocouple measurement will decrease.

Expected scientific contribution

Devices and methods developed within this research will facilitate the examination process of thermocouples and increase reliability of its measurement capabilities. All parts of temperature traceability chain, from primary laboratories to end users, will benefit from the improved accuracy of thermocouple measurement

Keywords

Temperature, thermocuople, measurement uncertainty, verification

Development and Application of Photocatalysts Based on Titanium Dioxide/reduced Graphene Oxide Nanocomposites

PhD candidate: Martina Kocijan
Mentor/s: Lidija Ćurković
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Heterogeneous photocatalysis based on titanium dioxide (TiO_2) is the one widely used because of the extraordinary properties for degradation of organic matter under UV light irradiation, their low environmental impact, and cheapness. The major pitfalls in the practical application are the wide bandgap energy and quick recombination of the photogenerated electron-hole pairs. These limitations have very low efficiencies in the decomposition of effluent compounds under solar light. Sunlight irradiation has around 3-5% of UV light, and almost 45% is visible-light. To overcome these limitations, new photocatalysts based on the TiO_2/reduced graphene oxide (rGO) nanocomposites are being designed. The rGO has been investigated because of its excellent properties. Thus, TiO_2/rGO nanocomposites give us an interesting opportunity to design photocatalysts with extraordinary properties, which can shift photodegradation to the visible-light range of sunlight irradiation.

Aims

The aims of this study are a synthesis of graphene oxide (GO), TiO_2/rGO photocatalyst, and a comparison of the properties of the obtained materials with different characterization techniques and investigate the effect of various amounts of GO and synthesis parameters on the photoactivity. The achievement of these aims, i.e. the development of new TiO_2/rGO nanomaterial with excellent photoactivity under sunlight irradiation would allow the wastewater treatment as environmentally friendly and low-cost photocatalyst methods.

Methods

The Hummer's method will be used natural graphite powders, H_2SO_4, $NaNO_3$, $KMnO_4$, and H_2O_2. A colloidal solution of the TiO_2 sol will be prepared using: titanium isopropoxide, i-propanol, nitric acid, and acetylacetone. The TiO_2/rGO photocatalyst will be synthesized by the hydrothermal procedure followed by calcination treatment. In order to obtain a nanocomposite of exceptional photocatalytic properties, it is necessary to determine precisely the optimal parameters of hydrothermal synthesis as well as the optimal content of graphene oxide. The properties of the synthesized composite will be investigated by different characterization methods including P-XRD, Raman spectroscopy, SEM/EDX, XPS, FT-IR, and DRUV-Vis spectroscopy. The synthesized photocatalyst will be applied to the removal of organic pollutants by ultraviolet and visible light irradiation to estimate their photoactivity under natural conditions.

Expected scientific contribution

The expected scientific contribution of this study is the development of new photocatalysts based on the TiO_2/rGO nanocomposites using cost-effective and simple methods. The TiO_2/rGO nanocomposite with exceptional photodegradation properties under solar light irradiation can be used as high-efficiency and green photocatalysts for the removal of an organic pollutant from water/wastewater.

Keywords

Heterogeneous photocatalysis, Graphene oxide, TiO2/rGO nanocomposite, Ultraviolet and visible light irradiation; Wastewater treatment

Adaptive Control of a Plug-In Hybrid Electric Vehicle Considering Driving Cycle Features Variability

PhD candidate: Mislav Hihlik
Mentor/s: Joško Deur
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

In recent years, electrified vehicles have been increasingly adopted by public. Hybrid-electric vehicles (HEV) or plug-in hybrid-electric vehicles (PHEV) impose as an excellent stepping stone to the full-electric vehicles (FEV) deployment due to their bridging of main FEV shortcomings: relatively short range, high cost of energy storage and long charging times. In order to increase the vehicle powertrain efficiency, it is necessary to design a control system which adaptively utilizes both energy sources to reduce the amount of energy consumed.

Aims

The aim of this research is to develop an adaptive PHEV control strategy which minimizes fuel consumption, improves driveability and comfort by taking driving cycle features and driving style into consideration. Suggested control strategy is going to be systematically verified against dynamic programming (DP) benchmark, quantifying the improvements achieved by applying adaptive and predictive mechanisms and assessing transferability to other PHEV powertrain configurations.

Methods

DP optimisations will be conducted for the forward-like PHEV model and over a wide set of synthetic driving cycles covering different driving conditions. The control parameters will be found for each discrete time step in order to achieve the equality between the control variables from the control strategy and the DP optimisation results. The most influential control strategy parameters will be identified, which will finally be the candidates for adaptation with respect to driving cycle features. A correlation analysis of the statistical driving cycle features, with respect to the optimal control parameters will be performed. The adaptation law will then be established on a regression model relating these two set of variables. Since the adaptation law is initially derived from the DP optimisations based on the forward-like PHEV model it will further be refined for the full forward-looking model based on using parametric optimization.

Expected scientific contribution

Firstly, novel optimisation-based methodology for extracting significant driving cycles features will be proposed. Upon that, design of an adaptive PHEV control system that continuously adjusts the most influencing control strategy parameters with respect to on-line estimated and predicted statistical driving cycle features, compared to the discontinuous adjustments covered in the literature, will be conducted. Lastly, control strategy adaptation with respect to prediction of statistical driving cycle features and the scheduled optimal SoC reference trajectory is expected to be developed.

Acknowledgments

It is gratefully acknowledged that the research work of the author is supported by the Croatian science foundation through the „Young researchers' career development project – training of new doctoral students" and ACHIEVE (Adaptive and Predictive Control of Plug-in Hybrid Electric Vehicles) projects.

Keywords

Plug-in hybrid electric vehicle, optimization, driving cycles, adaptive control, prediction mechanisms

Energy Absorption of Aluminium Foams

PhD candidate: Ivana Bunjan
Mentor/s: Krešimir Grilec
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Global warming, air pollution, and the shortage of fossil fuels are increasingly affecting the well-being of society, creating enormous pressure on the industry. Only the transport sector is responsible for 25% of the greenhouse emissions in Europe. Therefore, weight reduction is regarded as one of the major priorities to reduce emitted pollutants and fuel consumption. Metallic foams, e.g. aluminium foams, have been attracting considerable attention in automotive applications. They have unique properties such as low density and good energy absorption characteristics which can make vehicles lighter. Aluminium foams are man-made artificial cellular solids that have many applications in the automotive, biomedical, aerospace, and engineering industries in general. They can be used in the area of blast energy absorption because they can absorb kinetic energy from impact and can delay and attenuate stress waves. They can undergo plastic deformation at a nearly constant stress level, over a wide range of strain. This makes them ideal for energy absorption.

Aims

The aim is to investigate fracture zones on microscale and effect of different densities, as in energy absorption properties. The extent of production and pressure can be varied to make foams with different shapes and sizes and to achieve replicability of aluminium foams.

Methods

Aluminium foams are produced with various methods, such as powder metallurgy technique, sintering technique, the addition of a gas in melt injection, investing casting, and using an agent in melt foaming. Aluminium foams made via powder metallurgy technique by heating a compacted mixture-foamable precursor made of aluminium alloy powders, and foaming agents, typically TiH_2, which releases hydrogen gas into the liquefied compact of aluminium foam. The cellular structure is then created. The usual way to determine the compressive mechanical properties of produced aluminium foams is uniaxial tensile testing to investigate energy absorption capacity. The engineering stress – engineering strain curves are then produced with information about the plasticity of the material, energy absorption capacity, and where cracks appear. Digital image correlation (DIC) is applied to describe local strain fields and it is suitable for a comprehensive description of the quasi-static mechanical behavior of materials. The method used for capturing temperature distributions in high dynamic processes is infrared (IR) thermography. These methods are also suitable for further thermoelastic stress analysis where the stress intensity in the samples, as well as the points of stress concentration can be determined.

Expected scientific contribution

Aluminium foams are relatively new material, but with the change of producing parameters and mechanical testing different results will be obtained. A combination of different methods in research can give the opportunity to better understand them, and eventually, to successfully implement aluminium foam parts in the automotive industry. Some gaps will be filled for energy absorption behavior – studies about the effect of high nominal relative densities are not so abundant in the literature.

Keywords

aluminium foams, energy absorption, non-destructive methods, mechanical testing

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

PhD candidate: Luka Balatinec
Mentor/s: Hrvoje Jasak
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Even with the continued electrification of personal and commercial vehicles and a global shift towards renewable and clean energy systems, rolling contact bearings and other loaded contact pairs remain a vital part of modern engineering systems. From the drive-train of electric vehicles to power transmission systems of wind turbines, such elements must endure high-load conditions, going through a large number of operating cycles, while remaining reliable structurally and keeping up with demands for higher efficiency and decreased friction losses. That is why having a reliable lubrication model applicable to all lubrication modes and different lubrication mixtures, along with an adequate wear model, would result in a tool capable of numerical assessment of performance and lubrication of loaded contact elements. Such a tool could be invaluable for the investigation of interactions between device elements and different lubricants, prediction of wear, the effects of lubricant fluids on the reduction of friction and wear, etc.

Aims

The ultimate objective of the work presented here is to develop a numerical model capable of predicting long-term surface wear in situations of highly loaded lubricated mixed-mode contact. The model should be sensitive to input parameters such as: surface roughness, load parameters and lubricant formulation. As the widely available contact models in Finite Volume Method contact analysis framework are considered inadequate, development of an improved lubrication model is required and will be investigated as part of this research. What is more, an implementation of a proof-of-concept wear model into the lubrication modelling framework will be introduced. Starting from a relatively simple wear model based on the Archard Wear Equation, the wear model shall be expanded further, implementing existing micro-scale models based on the thermodynamics of friction and wear.

Methods

This research is a purely numerical investigation of the aforementioned phenomena. The numerical framework will be developed using the Finite Volume Method and will be implemented as part of the open-source multidisciplinary Computational Fluid Dynamics (CFD) toolbox foam-extend (community driven fork of the OpenFOAM numerical simulations library).

Expected scientific contribution

The development and validation of an improved numerical model is expected, as well as the development and implementation of a wear algorithm in the Finite Volume framework, which is to be applicable to contact problems with wear phenomena and verified against experimental data.

Keywords

Lubrication, Wear, Contact Analysis, Finite Volume Method, OpenFOAM

Co-Pyrolysis of Biomass Sawdust and Waste Plastics; the Influence of Mixture Compositions on Synergistic Effect and Liquid Product Yield

PhD candidate: Hrvoje Stančin
Mentor/s: Neven Duić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Decarbonisation of the transport and industry sectors, besides electricity, requires the utilisation of various alternative fuels for high-temperature processes and some form of transportation. Biodiesel is the most prominent alternative, even though lower heating value, high moisture and oxygen content, followed up by lower thermal stability, higher viscosity and acidity constraints wider deployment. Lately, co-pyrolysis of biomass with waste plastic is introduced as the promising solution to enhance the properties of derived biofuels, simultaneously dealing with waste management problems. During the co-pyrolysis interaction between feedstock promotes the synergistic effect, responsible for the distribution of obtained products. A synergy is evident when the obtained experimental values are higher than those theoretically calculated. Positive synergy is almost always reported for solid fraction, as a consequence of ash, and fixed carbon content in raw feedstock. Synergy for the liquid and gaseous fraction depends on process conditions, but even more on feedstock selection. Influence of feedstock selection is especially interesting when waste materials like sawdust and plastics are used in fuel blends. Besides the type of used feedstock, the mixing ratio has a strong influence on achieved synergy. Therefore, this work will aim to evaluate the influence of plastic content on synergistic effect and product yield. Even though the addition of plastics significantly improves the properties of bio-oils, a higher share of various pollutants and harmful compounds limits its share in fuel mixtures. In general, plastic favours liquid yield, increases heating value and improves the thermal stability of bio-oils.

Aims

The aim of the research is to produce high-quality bio-oil from the co-pyrolysis of biomass and waste plastic that could be further utilised as an alternative fuel. Additionally, specific objectives are to determine the level of synergy that occurs between investigating feedstock, and the most influential parameters responsible for the product distribution.

Methods

The research is of experimental nature. The main method for the production of bio-oil is the pyrolysis, coupled with mass spectrometry and gas chromatography for identification of obtained products. Additionally, thermal decomposition mechanisms will be analysed using various kinetic models to determine the level of synergy between investigated feedstock.

Expected scientific contribution

The obtained results will be of great significance for understanding the thermal decomposition mechanism of investigated materials, and the influence of plastic content on bio-oil quality. Additionally, the research will strive to provide an in-depth analysis regarding the influence of feedstock selection on product yield and distribution, which is crucial for scaling up the process on an industrial level.

Keywords

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

Numerical Method for the Evaluation of Structural Response of Ship Appendices

PhD candidate: Andro Bakica
Mentor/s: Nikola Vladimir
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Modern ecological demands and ship-owners continuous need for the reduction of fuel consumption have become an unavoidable criterion in ship design. Novel method for reducing the fuel oil consumption in the shipping industry is the installation of ship appendices called the Energy Saving Devices (ESDs). Such devices mainly increase the propeller efficiency through hydrodynamic interaction with the propeller. Although their performance has been proven numerous times with respect to the experimental and computational methods, structural design aspects of ESDs are more or less vaguely investigated. Subjected to non-standard hydrodynamic loads induced by ship motion in waves, combined with the lack of firm and straightforward classification rules, the level of their structural integrity remains unclear.

Aims

The topic of this research is the development of the numerical method for the evaluation of the structural response of ship appendices exposed to wave loads and the computational tool for coupling between the fluid and structural solvers. There are two equally critical steps to be taken into account: the development of the numerical method accounting for the whole ship life cycle and the development of the efficient hydro-structure interaction tools for consistent evaluation of the structural stresses induced by wave loads. First step is related to the statistical analysis of all probable sea states while the second step is a general problem of fluid structure interaction (FSI). There are two principal approaches when assessing the FSI problems which are usually called the one-way or two-way coupling and these classifications depend mostly on the simplifications when solving the physical problem. In this thesis, the structural solver is always assumed linear irrelevant of the communication type between the fluid and the structural solver.

Methods

For the statistical analysis of the relevant sea states which the ship will encounter during its life-cycle a potential flow code HydroStar by Bureau Veritas is used. Solution is acquired in frequency domain which makes this approach highly beneficial for large amount of sea state data analysis. Assuming critical sea states are distinguished, a non-linear analysis can be performed. For the non-linear flow solution a Computational Fluid Dynamics (CFD) solver OpenFOAM is employed with the Finite Element Method (FEM) solver Nastran. Interface between the two computational tools is made in the framework of OpenFOAM using object oriented programming paradigm in C++. Depending on the physical problem, the coupling can then be established (static or dynamic).

Expected scientific contribution

The expected scientific contribution of this thesis consists of the following:

1. Numerical method for the analysis of structural response of ship appendices.

2. Mathematical model for coupling of CFD and FEM.

Acknowledgments

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Keywords

Energy Saving Device, CFD, potential flow, FEM, fluid-structure interaction

Influence of the Magnetic Field on Water Electrolysis

PhD candidate: Matej Paranos
Mentor/s: Ankica Kovač
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Process of water electrolysis for hydrogen production in combination with renewable energy sources, such as solar and wind energy, represent an essential part of a clean hydrogen-based economy. The possibilities of increasing the efficiency of this process are the subject of numerous studies conducted around the world, making it ever more competitive and accessible to a wide range of users.

Aims

One of the possible ways to increase the efficiency of the water electrolysis process is the application of the magnets and usage of the magnetic field to enhance the process. This is somewhat confirmed by first conducted research in this field, which results indicate that the Lorentz force, created as a result of the existence of magnetic field and direct electric current in electrolyte, has a positive effect on the electrolysis process with the smooth-surface electrodes. One of the main tasks of research in this work is to determine the effect of magnetic field on the electrolysis of water in an alkaline electrolyzer using nickel (Ni) foam electrodes.

Methods

In order to prove and calculate the intensity of this impact, an experimental study is being conducted on an electrolyzer developed in the Power Engineering Laboratory at the Faculty of Mechanical Engineering and Naval Architecture. Although all previously conducted research suggests that application of the magnetic field enhance hydrogen production efficiency, they vary in describing the amount of the impact it has on the process. Therefore, along with research conducted with the Ni foam electrodes, experiments with smooth-surface electrodes are being conducted as well to determent characteristics of electrolyzer.

Expected scientific contribution

This extensive comprehensive experimental research will contribute to the current theoretical knowledge and enable design of reliable mathematical model for future development.

Acknowledgments

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

Keywords

Hydrogen-based economy, alkaline water electrolyzer, magnetic field, Lorentz force

Constitutive Modelling of 3D Printed Polymers and Application in the Design of Arterial Replicas

PhD candidate: Toni Škugor
Mentor/s: Igor Karšaj
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Nowadays, additive manufacturing has arisen as one of leading technologies in the production of medical devices, implants and replicas. PolyJet 3D printing technology provides a vast range of polymers, named digital materials, based on mixing of two base materials in different ratios, soft TangoBlackPlus (TBP) and stiff VeroWhite. Furthermore, it allows simultaneous 3D printing of two polymers which could represent elastin matrix and collagen fibres, the main constituents of arterial wall. Both constituents have specific mechanical properties which endeavour to be replicated by 3D printed polymers.

Aims

The main goal of this work is to develop an adaptable design procedure for manufacturing arterial replica which can be customized for a specific artery. The first step is accurate and successful experimental testing of 3D printed polymers. The following step includes accurate constitutive modelling in order to describe hyperelastic, viscoelastic and softening properties. Material parameters acquired through constitutive modelling will then be used as an input for numerical simulations. Change in geometry e.g. radius of collagen fibre and selection of material can allow adjustments to overall replica behaviour. At the end, manufactured arterial replica will be experimentally tested under physiological conditions and compared to real tissue.

Methods

Experimental testing required for appropriate mechanical characterization of 3D printed polymers involves cyclic and failure uniaxial and biaxial tensile testing. Materials selected for experimental testing were TBP and six digital materials from flexible group. Samples were manufactured using Objet350 Connex3 3D printer (Stratasys). Uniaxial samples were 3D printed both longitudinally and transversely to check for differences in ultimate tensile strength and strain due to 3D printing orientation. Uniaxial tensile tests should be conducted at different strain rates as it can have significant effect on the ultimate tensile stress and strain. Materials' anisotropy will be examined in the plane stress state during biaxial tensile testing with different stretch ratios. Non-linear least square method will be used to determine material parameters from experimental results. Multiple strain energy density functions should be analyzed to determine the best fit.

Expected scientific contribution

Current research in the field of arterial replicas is mainly based on the 3D printing precision and accuracy in replicated geometry. There is a scarce number of studies focused on arterial replicas mechanical properties. Developing arterial replicas with mechanical properties corresponding to real tissue could support future hemodynamic studies. Further benefits include the preparation of medical procedures or training of inexperienced surgeons.

Acknowledgments

This work was supported by grants from the Croatian Science Foundation (project IP-2018-01-3796, D. Ozretić) and project Training of New Doctoral Students (DOK-2018-09-9116).

Keywords

Hyperelasticity, Viscoelasticity, Softening, Experimental testing, Arterial replicas

Frequency-Shifting-Based Algebraic Approach to Extended State Observer Design for Fully Actuated Mechanical Systems

PhD candidate: Antonia Penđer
Mentor/s: Josip Kasać
Affiliation: Zagreb University of Applied Scineces, Croatia

Introduction

Nonlinear dynamics systems with unknown dynamics and partially measurable state variables, in presence of external disturbance, is major challenge for disturbance rejection control. Compensation methods based on extended state observer (ESO) aroused interest in recent years. ESO provides simultaneous estimation of system states and total disturbance that represents aggregation of internal and external uncertainties. ESO is used as central point in active disturbance rejection control (ADRC) that has proven to be effective with minimal model information. Its disadvantages are presented in limited accuracy of disturbance estimation, high-amplitude transient oscillations and sensitivity to noise and sudden disturbances. In parallel with development of the ADRC, algebraic approach to ESO design has emerged. It provides non-asymptotic convergence to the true values that resolves the problem of high-amplitude transient oscillations. It is characterized with robustness to initial condition and measurement noise. The main disadvantage is unstable dynamic realization. This problem is solved recently using frequency-shifting-based (FSB) approach in design of the estimator where instead of conventional derivative based annihilator, finite difference annihilator is used in complex domain.

Aims

The main goal is to develop stable FSB algebraic state and disturbance observer that will enable non-asymptotic convergence. Additional benefits would be robustness to noise and sudden changes. Algebraic approach will be used in regulator synthesis to eliminate transient response sensitivity to initial condition that is characteristic to conventional linear regulators

Methods

Research will be focused on development of mathematical algorithms for synthesis of FSB algebraic estimators with application in mechanical systems control. Algorithms will be implemented in software package Matlab and numerical simulation results will be presented for servo DC motor control. Mainly, Laplace transform will be used, with an emphasis on the properties that allow the application of finite difference operator for annihilation of initial condition. State space realization will enable estimator implementation in real time. The final estimates will be determined from the state variables.

Expected scientific contribution

FSB algebraic method used in estimator design was recently proposed, so there has been not much research done on the subject. Algebraic approach provides opportunity to successfully address limitations of ADRC methodology. Initial framework for this paper was used from previous research done on implementing FSB approach in state estimation of second order system. Here, third order system will be used in design of estimator that will be implemented on second order system enabling us to estimate position, velocity and acceleration from measured position. Estimation of total disturbance will also be obtained.

Keywords

active disturbance rejection control, algebraic state estimation, extended state observer, frequency-shifting-based approach

Influence of Surface Preparation of Titanium Alloy on Adhesion Strength of Coatings

PhD candidate: Dražen Mezdić
Mentor/s: Suzana Jakovljević
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

As it is known, all parts used in transportation, production, and energy generation are made up of moving parts whose surfaces are in contact with each other. In order to extend their service life, it is necessary to study the friction between the materials in contact. Friction and wear are closely related to the appearance of surfaces and the choice of tribo-pair. Uneven surfaces lead to increased material wear, and it is well known that surfaces are not ideally smooth. From the microscopic point of view, rough surfaces are described by a series of irregularities of different shapes, arrangements, and sizes. For titanium and its alloys, mechanical pre-treatment of surfaces is emphasized to the greatest extent. Titanium alloys are widely used in aeronautical and medical applications as implants because of their high mechanical properties, such as strength, and biocompatibility. However, the biggest problem with these alloys is their low wear resistance and therefore requires low surface roughness. Surfaces thus prepared, after microhardness, roughness, and wetting angle tests, show that the negative tribological properties are reduced. Therefore, the main lack of low wear resistance limited the widespread use of Ti6Al4V alloy in medicine. In the human system, when Ti6Al4V is worn, corrosion can occur, which can lead to accelerated implant breakdown, which limits long-term stability.

Aims

The aim of the research is to find optimal surface roughness using new technologies in order to achieve the best possible adhesion of the coating on Titanium alloy.

Methods

The material intended for the research is titanium alloy Ti-6Al-4V. It is characterized by a right combination of high strength and low modulus of elasticity, high resistance to fatigue and wear, and high ductility. The surfaces of the coating samples will be prepared by mechanical pre-treatment of polishing and subsequent laser treatment in order to achieve the most uniform topography of the surface and thus better adhesion between the coating and the base material. The surface coating will be carried out by steam phase procedures – PACVD and PVD. The coatings will be applied so that the thickness will change depending on the surface roughness profile. Detailed characterization and analysis of the coating will be performed, which includes: analysis of the composition of surface layers (GDOES, EDS), electrochemical tests, testing of adhesion of coatings by Rockwell method and scratch test, measurement of coating thickness by ball indentation method (calotest), ball on flat and block on ring methods, determination of wetting angle, testing of coating nano hardness, measurement of coating roughness parameters and base material, and analysis of coating microstructure and roughness profile by scanning electron microscope (SEM).

Expected scientific contribution

The results of the research will significantly contribute to a better understanding and optimization of the surface preparation itself for coating properties. Also, the contribution is expected in the adoption of new technologies in the field of surface engineering, which will create a new basis for further research of existing and new materials.

Keywords

Surface roughness, wear, adhesion, topography

Surface Hardening of Titanium Alloy Ti6Al4V Produced by Additive Technologies

PhD candidate: Josip Pranjić
Mentor/s: Darko Landek
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Titanium and its alloys have good mechanical, corrosion, and biomedical properties that can be further improved by alloying and heat treatment, however, the wear resistance of these alloys remains lower compared to ferrous materials with similar mechanical and corrosion properties. The application of titanium alloys in structures with the requirement of reduced mass, good mechanical properties, and corrosion resistance is enabled by the production of parts by additive sintering and remelting technologies by a laser beam or electron beam. The surface of titanium alloys made by additive technologies requires additional machining to obtain the shape, dimensions, topography, and surface roughness suitable for assembly and operation of the product. For the application of titanium alloys produced by additive technologies, the influence of heat treatment and the possibility of increasing wear resistance by applying surface modification and coating procedures has not yet been fully investigated. The proposed study plans to conduct a systematic study of the impact of heat treatment and various combinations of surface hardening by mechanical and thermal processes and PACVD coating TiN, TiCN, and TiBN coatings on mechanical, corrosion and tribological properties of Ti6Al4V alloy produced by selective laser melting and melting. Based on the conducted research, it is planned to develop an experimental model for predicting the properties and selection of the optimal duplex procedure for hardening the surface of Ti6Al4V alloy.

Aims

Aim of the research is to develop new surface hardening duplex process of additive manufactured Ti64 alloy whereby will be produced new surface layer with improved mechanical properties and enchancing wear resistance.

Methods

The research plan is divided into three phases. The first phase will encompass manufacturing the samples by additive manufacturing methods including SLM and EBM. The second phase will include the characterization of samples by numerous methods such as GDEOS for chemical composition, and surface roughness will be conducted by profilometry. Proposed methods of material characterization will determine the number of properties characteristic of the base material and the surface layer. By applying statistical analysis methods and setting up an artificial neural network model, it is planned to conduct research and evaluate the influence of combinations of pre-processing parameters on the properties of the duplex layer. Based on the developed model, a method of evaluation and selection of the optimal heat treatment process and a duplex surface hardening layer for Ti6Al4Vballoys produced by additive technologies with melting and sintering of metal powder will be proposed.

Expected scientific contribution

Anticipated methods of statistical analysis and applied model of artificial neural networks will produce best parameters for conducting heat treatment and evolving finest surface layer for surface hardening of additive manufactured Ti64 alloy.

Keywords

Ti6Al4V alloy, additive technologies, SLM, EBM, PACVD, duplex layer, TiN, TiCN, TiBN, corrosion resistance, wear resistance

Development of Nanoscaled Hardmetal Materials for Wear-Resistant Tools

PhD candidate: Andrea Ladavac
Mentor/s: Tamara Aleksandrov Fabijanić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Hardmetals or cemented carbides display a great combination of properties such as high hardness and good fracture toughness. With the combination of these properties, hardmetals have found use in a wide range of products such as tools and wear resistant parts. The most common used types of hardmetals consist of a hard ceramic phase mainly tungsten carbide and binder phase such cobalt, iron and nickel. Where the mechanical properties can be adjusted by varying the amount of binder phase and WC grain size. The hardmetals hardness comes from the hard-ceramic WC phase. Therefore, an increase in hardness can be achieved by lowering the amount of binder phase and by decreasing the grain size. To achieve a smaller grain size, grain growth inhibitors are used which slow the growth of the ceramic phase during the sintering process. Hence, binderless nanoscaled hardmetals are mainly used for tools that require high hardness and wear resistance.

Aims

Development of innovative hardmetal materials using advanced technological solutions. The main focus of the research is attaining a hardmetal material with a hardness over 2500 HV. Thus, obtaining excellent wear resistant that outperforms conventionally WC/Co hardmetals.

Methods

A series of preliminary powder mixtures were prepared. Every mixture has a variation of input parameters such as carbon content, mixing time, drying time, binder phase content and grain size. The prepared mixtures were sintered on various temperatures in order to investigate the effect of different sintering temperatures on the mechanical properties. Material characterization methods and hardness tests will be conducted in order to investigate which optimal parameters need to be utilized for the development wear resistant nanoscale hardmetal.

Expected scientific contribution

The development of a new binderless nanoscaled hardmetal materials using unconventional grain growth inhibitors and sintering temperatures. While producing a wear resistant compound that would outperform the ultra-fine hardmetals that are commonly used in the industry. Thus, innovating in the field of hardmetals and powder metallurgy.

Acknowledgments

This work has been fully supported by the European union from the European Regional Development Fund under project Nano-Pro KK.01.2.1.01.0079.

Keywords

Powder metallurgy, hardmetal, nanoscaled, hardness, binderless

Rapid Tooling of Mould Inserts for Injection Moulding with Metal-Filled Epoxy Composites

PhD candidate: Tomislav Breški
Mentor/s: Damir Godec
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Injection moulding technology is currently one of the most widely used technologies for production of polymeric parts. This technology is constantly evolving, and currently, most notable advances in this field are achieved in the field of mould design and optimisation. Using additive manufacturing technologies, either directly or indirectly it is possible to produce moulds with complex geometries that have optimal cooling in every point of mould cavity. Since the production of entire mould is very time consuming, rapid tooling approaches have shown great success in shortening mould production time with additional advantages in the field of conformal cooling of injection moulds. Time-to-market is very important in this industrial field, and by utilizing production methodologies for prototype injection moulds certain flaws in mould design can be addressed in short amount of time. In this research indirect rapid tooling utilizing metal-filled epoxy composites methodology is investigated. Since thermal properties of materials are very important in injection moulding, polymeric materials used as mould materials are not feasible. Latest research has shown that by filling the epoxy resin with appropriate amount of metallic particles thermal properties of given composite are substantially increased. By utilizing such composite as mould material, it is possible to produce mould prototype in short amount of time with potential increase in thermal efficiency which results in increase of production cycles this prototype mould can withstand before mechanical degradation.

Aims

Aim of this research is to define a methodology for production of injection mould inserts made with metal filled epoxy composites. Thermal efficiency of such moulds need to be experimentaly verified against numerical approximations from CAE software for injection moulding. Furthermore, influence of inclusion ofconformal cooling channels in such injection moulds will be investigated with regard to mould thermal efficiency.

Methods

By utilizing design of experiment methods metal filler to epoxy resin ratio will be evaluated in order to achieve optimal thermal properties of prototype mould material. With such material mixture prototype mould insert will be produced with indirect approach utilizing additively manufactured mould negative. Numerical values of temperature distributions calculated in CAE software in such mould will be verified on experimental setup which measures temperature of specific points inside prototype mould insert which is included in injection mold process.

Expected scientific contribution

This research will provide new production methodology in the field of indirect rapid tooling of injection mould inserts. Results achieved in this research will show whether conformal cooling is feasible in such mould insert.

Acknowledgments

I would like to express my very great appreciation to company AUTODESK INC. for granting access to MoldFlow Insight CAE software.

Keywords

Injection moulding, rapid tooling, metal-filled epoxy composites, conformal cooling

Wind Loads on Tall Buildings with Porous Double-Skin Facades

PhD candidate: Petar Škvorc
Mentor/s: Hrvoje Kozmar
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Double skin facade (DSF) is a buildings envelope system which consists of two facades with a gap between the inner and outer facade. There are several advantages in using such a system, e.g. thermal insulation, rain protection, sun blockage and visual appeal. If the outer facade is porous, the cladding system is defined as a permeable double skin facade. A porous outer facade maintains the benefits of sun blockage and it also protects the inner facade from atmospheric elements to a certain degree. It is likely that the porous outer facade alters the fluid-structure interaction between the building and the atmospheric boundary layer flow. However, reliable and robust data on aerodynamic properties of porous DSF are still unavailable at this moment.

Aims

The aim of this ongoing research is to experimentally determine the aerodynamic properties of a tall building with porous DSF system. The measurements are to be performed on small-scale building models in a boundary layer wind tunnel by using the high-frequency force balance to determine integral forces and moments acting on building models, and pressure taps to determine local pressure characteristics on the critical parts of the inner building facade. Prior to those experimental investigations, computational analysis has been performed on a two-dimensional section of a rectangular cylindrical building with and without a porous DSF to elucidate fundamental flow and surface pressure characteristics of the bluff-body aerodynamics.

Methods

A two-dimensional computational model is developed based on the Finite Volume Method (FVM). The flow is considered viscous and incompressible and modelled using the Unsteady Reynolds-averaged Navier-Stokes equations (URANS) and the k-ω SST turbulence model. Second order implicit scheme was employed for time discretization and the second order upwind scheme for spatial discretization. Discretized equations were solved by Semi-Implicit Pressure Linked Equations (SIMPLE). The results were validated using the available experimental results for airflow around a two-dimensional square prism. The computational results encompass the average velocity and pressure fields, the drag and lift force coefficients, and the vortex-shedding frequency characteristic of a two-dimensional square prism.

Expected scientific contribution

The results of this research will provide a better understanding of aerodynamic characteristics of tall buildings with porous double-skin facades for various porous DSF systems, flow incidence angles, turbulence and building height.

Acknowledgments

The Croatian Science Foundation IP-HRZZ-2016-06-2017 (WESLO) support is gratefully acknowledged.

Keywords

Tall building, Porous facade, Aerodynamic loads, Laboratory experiments, Computational Fluid Dynamics

Efficiency Improvement in Cccgt Plants and Associated New 4Thgdhs by RES Integration

PhD candidate: Perica Jukić
Mentor/s: Zvonimir Guzović
Affiliation: HEP ESCO d.o.o., Croatia

Introduction

The economy of CCCGT plants (Combined Cycle Cogeneration with Gas Turbine) largely depends on very unstable electricity prices on the market. This trend will intensify in the future due to additional integration and utilization of RES (Renewable Energy Sources). Analyzing this techno-economic area, most of the different operational objectives, DHs (District Heating systems) and CCCGT plants must find a way to cover costs and operate efficiently in the future. One of the way is integration of RES on both side, CCCGT and DHs. Consequently temperature of DH system will be much lower and conditions can be met to switching to 4^{th}GDHs (4^{th} Generation of DH system). Integration of RES and Switching to 4^{th}GDHs will significantly reduce primary energy consumption and CO_2 emissions.

Aims

This Thesis is analyses the possibilities of efficiency increase of the largest CCCGT plant owned and operated by HEP (Croatian Electric Power Utility Company) and its connection to new DH system in Republic of Croatia. In some parts of the municipality, HP (heat pumps) are possible integrated in the return lines of the DH system, to lift the heating potential and increase the local generation of heat energy, which in turn increases the efficiency of the DH system and the CCCGT plant. At the CCCGT plant heat pumps are possible integrated at the outlet of cooling system which serves as a heat source for its operation. An integration of SDHs (Solar DH system) also is possible integrated at an open space and connect to new DHs.

Methods

The research methods involved in this Thesis shall include energy calculation and experimental measurements on an actual facility to find optimal mode of operation. That include RES integration and 4^{th}GDHs operation under different weather conditions. By mathematical model shall be developed which represents an energy characteristic of a CCCGT plant, together with energy characteristic of HPs and SDHs which shall enable a calculation of economical operating regimes. The experimental part of the research shall comprise measurement of relevant variables on various operating regimes of the CCCGT plant and associated district heating power plant. Measurement results shall be used to validate results obtained with the mathematical model and eventually to improve the mathematical model itself. The calculation results obtained with the mathematical model for various operating regimes shall serve finally for a complete techno economical analysis.

Expected scientific contribution

Getting familiar with the scientific methods and solutions that lead to increased efficiency in the existing CCCGT plant and the associated DH system is a benefit to the wider scientific community and energy companies. The resulting mathematical models and energy characteristics will serve to create a mathematical model for other CCCGT plant and associated DHs by RES integration. It will also strengthen scientific cooperation between Croatian Electric Power Utility Company and the Faculty of Mechanical Engineering and Naval Architecture.

Acknowledgments

I would like to thank my Mentor Professor Zvonimir Guzovic an Professor Neven Duic for them guidance and patience. I also would like to thank my company HEP for support in this investigation and my director Željko Jelačić.

Keywords

Efficiency increase, CCCGT plant, 4th GDHs, Integration of RES, HP, SDHs, Mathematical model

Investigation of Thin Sheet Structures Under Complex Loading Regimes

PhD candidate: Andrija Zaplatić
Mentor/s: Zvonimir Tomičević
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The production of engineering components in which metal forming is employed on thin sheets strongly depends on the mechanical parameters in the numerical simulations used to model and optimize the final product. Material parameters obtained by a simple tensile test are not sufficiently reliable to describe the material behavior under multiaxial loading conditions. Hence, additional experimental investigations need to be carried out. In order to accurately predict springback during the forming process, it is necessary to characterize the response of thin sheets subjected to complex loading. Specially designed grips or/and corresponding sample shapes suitable for uniaxial testing devices are used to prescribe in-plane loading histories. The most commonly used in-plane testing configuration coupled with tensile loading machine is achieved with the modified Arcan fixture. The proposed rig enables for the application of pure tensile, simple shear and mixed-mode loadings. The development of the optical measurement methods enabled the observation of full-field displacement and strain maps. Digital Image Correlation (DIC) stands out as the most widely used contactless full-field measurement method. Results obtained via global DIC approach (i.e. measured displacements at nodes of the finite element (FE) mesh) provide a straightforward connection with numerical simulations, thus an inverse problem for calibrating material parameters of the chosen constitutive law can be solved.

Aims

Aim of the suggested research is to improve an existing experimental setup for determining material response under complex in-plane loading. DIC will be an integral aspect within the proposed experimental setup. An identification routine which uses measured data (i.e. measured displacement field and measured load) from multiple experiments will be developed using the iterative Finite Element Model Updating (FEMU). Finally, the hybrid correlation method which simultaneously captures full-field displacement and thermal maps will be improved.

Methods

The proposed research will primarily be focused on developing the experimental setup in the beginning. Mechanical test will be carried out on the modified Arcan fixture coupled with the global DIC approach for full-field measurement. The measured kinematics will then be prescribed on the FE model as boundary conditions. The FEMU method will be employed for the calibration of material parameters by reducing the displacement and force residuals (i.e. the difference between the calculated and measured values). Furthermore, thermography method will be coupled with DIC in the hybrid correlation framework.

Expected scientific contribution

An improved experimental setup and identification routine, which combines measured data obtained from multiple experiments in a single procedure, will be developed. Such approach considers the material response under different loading regimes. As a result, more reliable material parameters can be calibrated for describing the material behavior with a single constitutive law. The implementation of hybrid correlation will provide more detailed insight into the material behavior and released thermal energy from plastic deformation and crack initiation and propagation.

Acknowledgments

This research will be performed within the FULLINSPECT project supported by the Croatian Science Foundation (UIP-2019-04-5460 Grant).

Keywords

Arcan fixture, DIC, inverse identification, FEMU, hybrid correlation.

Parametric Analysis and Optimization of Batch Distillation Process

PhD candidate: Danijel Zadravec
Mentor/s: Nenad Ferdelji
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Recent production increase of high-value-added, low-volume speciality chemicals and biochemicals in pharmaceutical, food and chemical industry gave rise to a renewed interest in batch distillation. One of the most important feature of batch distillation is its flexibility, which allows processing a variety of feed mixtures with different product specifications using the same equipment. Thus, it requires the least amount of capital for separating relatively pure components. At the same time, this flexibility and inherent dynamic nature of batch distillation processes pose challenging design, modelling and operational problems. Rigorous modeling of batch distillation operation involves solution of a multitude of stiff differential equations. Computational costs of such models are prohibitive for exploring large search-spaces. For optimization purposes, simplified short-cut methods are often employed, having restrictive assumptions which may not be acceptable in all cases.

Aims

The aim of the research is development and application of efficient batch distillation models suitable for optimization of equipment and control. Parametric analysis will be used to gain insight into the effect of various geometric and process parameters and their interactions on process performance indices. Local exergy destruction rate minimization will be considered as an optimization objective. Effect of various model assumptions will be evaluated by comparison with experimental measurement results.

Methods

For purposes of the research, efficient rigorous mathematical models with various levels of complexity will be developed. Models with different assumptions will be experimentally validated. Full factorial analysis of parameter effect on process performance will be conducted using the most accurate developed process model in combination with linear multiple regression. Most influential geometric and process parameters will be used for simultaneous optimization of equipment and process control. Multiobjective optimization will be conducted on the least complex adequate model using a non-dominated sorting genetic algorithm.

Expected scientific contribution

It is expected that this research will improve understanding of the effect which various parameters have on the batch distillation process. It will also provide criteria for assessment if model assumptions are reasonable. Finally, it will explore potential use of the local rates of entropy production and exergy destruction as performance indices for optimization of batch distillation design and control.

Keywords

Batch distillation, rigorous model, parametric analysis, exergy destruction

Development of Nanostructured Hardmetals with Alternative Binders

PhD candidate: Irbas Škrinjarić
Mentor/s: Tamara Aleksandrov Fabijanić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The development and research of nanostructured hard metals is a general trend in the field of modern technologies and is a subject of great importance. The development of nanostructured hardmetals is based on the application of powder nanoparticles (tungsten carbide grain size less than 200 nm) which show a significant improvement in properties. The goal is to prepare mixtures of different starting characteristics. Consolidation of nanostructured hardmetals will consist of compaction and sintering. Consolidation of the prepared mixtures will be carried out by procedures that represent the pinnacle of consolidation; sinter hot isostatic pressure process (sinter-HIP) and plasma sintering.

Aims

Aim is to prepare mixtures with different starting characteristics. In doing so, the content and type of matrix will vary; cobalt, nickel, iron or a combination of alternative binders, tungsten carbide powder characteristics and grain growth inhibitors; vanadium carbide, niobium carbide, titanium carbide, tantalum carbide and chromium carbide. By testing and detailed analysis, the aim is to determine the optimal consolidation parameters (grinding time and speed, ball / powder mass ratio, compaction pressure, sintering time and temperature, etc.) for each of the prepared mixtures and draw conclusions about the influence of mixture characteristics on final properties of developed materials. The test results will determine microstructural characteristics and grain size, degree of porosity, mechanical properties and corrosion resistance of innovative nanostructured hardmetals.

Methods

Analysis of physical properties (analysis of particle shapes and dimensions of selected powders on scanning electron microscopes, SEM and FE-SEM). In doing so, the method of quantitative metallography will be used to draw conclusions about the characteristics. The horizontal ball mill RM 1s will be used in the production of mixtures. Heptane and hardmetal beads will be used as the medium to prevent powder contamination during the grinding process. After the grinding process, the mixture will be dried to eliminate the liquid medium. The granulation will be carried out for the purpose of bringing the powder mixture into the flow property by means of a granulation sieve. Compaction will be carried out by the process of uniaxial compaction in a mold or cold isostatic pressing. Sintering will be carried out by various powder metallurgy processes; sinter hot isostatic pressure process and plasma sintering to examine the effect of the applied methods on the final properties of nanostructured hardmetals and to be able to conduct a later examination of the compatibility of the consolidation process.

Expected scientific contribution

The expected scientific contribution of this research is the development of innovative nanostructured hardmetals with alternative binders and corrosion resistant nanostructured hardmetals that will have a fine-grained, homogeneous microstructure and a significant improvement in mechanical and corrosion properties.

Acknowledgments

This work is supported in part by the Croatian Science Foundation under the Project Number UIP-2017-05-6538 Nanostructured hardmetals – New challenges for Powder Metallurgy.

Keywords

hardmetal, powder metallurgy, nanopowders, alternative binders

Key Obstacles in Making Non-Road Mobile Machinery Emission Inventories

PhD candidate: Šimun Lončarević
Mentor/s: Zoran Lulić
Affiliation: Energy Institute Hrvoje Požar, Croatia

Introduction

With the growth of global greenhouse gas emissions and their harmful effect on human health, there is a need for their control and decreasing. In order to reduce emissions, the European Environmental Agency (EEA) collects data from multiple pollutants. More stringent legal restrictions of engine emissions are also implemented on engines in non-road mobile machinery (NRMM), with similar regulations present in USA and China. Unfortunately, many countries do not have any type of an NRMM emission inventory, and most of those who do create their inventories based mostly on assumptions, with little to no data. An overview of the main problems concerning emission inventory for NRMMs and identifying main drivers towards solving those problems would help accelerate the process of making a NRMM emission inventory.

Aims

The aim of this research is to give an overview of the main problems which concern the process of making a NRMM emission inventory. Although research has shown that their contribution to overall emissions is significant, there is a need for a more serious approach towards acquiring and processing the data necessary to fully understand the ecological and health problems which they represent. Scientific research is the most important factor and future development depends on broadening current research. Identifying the main problems will help decision and policy makers to develop better environmental policies.

Methods

Firstly, there will be an overview of existing NRMM emission inventories. Special emphasis will be put on countries as Finland, Germany, Sweden and Switzerland, which have emission inventories. All of the aforementioned inventories indicate that the share of NRMM emissions is considerably larger than the share of energy consumption. Their methods of data collection and overall NRMM emission contribution compared to road vehicles will be evaluated.

Secondly, an overview of various research concerning NRMM emissions in several NRMM sub-categories will be made. Research in emission factors from different fuels, working conditions, different machinery etc. will be taken into account.

Thirdly, based on available scientific and government data, main obstacles towards making a NRMM emission factors will be researched. Moreover, recommendations towards solving said obstacles will be presented. A special case concerning Croatia will be examined based on available data.

Expected scientific contribution

The largest limiting factor in making an accurate NRMM emission inventory is that in most of the countries there is no repository of NRMM, especially hand-held devices, which makes almost impossible to make an accurate inventory of NRMM emissions. Without a systematic approach, research will continue to make a suboptimal contribution towards better understanding of the global impact of NRMMs. This research will identify the core obstacles which hinder the overall progress in researching NRMMs and making their emission inventories.

Keywords

ICE, emission factor, non-road mobile machinery, EU 2016/1628, emission inventory

Automatic Generation of Operation Plans in Robotically Assisted Neurosurgery

PhD candidate: Ivan Stiperski
Mentor/s: Bojan Jerbić
Affiliation: KBC Dubrava, Zagreb, Croatia

Introduction

In recent decade increasing attention in medicine is given to robotic systems with the aim of advancing surgical procedures. Standard procedure in stereotactic neurosurgery procedure starts with the scanning of the patient's brain using the Computer Tomography (CT) or Magnetic Resonance (MR) machine to obtain the tumor position data. Afterwards the surgeon plans the path called trajectory from the skull (Entry point) to the tumor (Target point). This procedure takes up surgeon's time and extends total duration of the operating procedure. It also requires the surgeon to have a certain amount of experience to make a good plan. To help the surgeons to use more of their time on the surgery and help the inexperienced ones to learn faster, an automatic planning algorithm is suggested. The algorithm is divided in two parts: segmentation and trajectory calculation. In segmentation part the goal is to take in the radiology scan of the patient's brain, filter it and label the parts of the brain through the whole volume. In trajectory calculation part the goal is to calculate a few trajectory suggestions on various important criteria like trajectory length, insertion angle and maximum distance from blood vessels. The algorithm will also include the optimal position of the surgical robot in the trajectory generation phase to reduce the need to know the robotic system and their optimal position by surgeons and medical staff.

Aims

The aim of this research is to make an algorithm for automatic trajectory suggestion for neurosurgical brain biopsy planning using the data obtained with radiology images from MR and CT machines. The goal is to make the introduction of new robotic stereotactic equipment in the neurosurgery procedure easier due to including the robot's position in the trajectory creation algorithm. The goal is also tom improve patient safety.

Methods

For segmentation part of the algorithm machine learning algorithms are implemented. Specifically, Convolution Neural networks (CNN) that are Deep Learning algorithm. Brain atlas method is also used for the same task of segmentation, where a brain volume is manually labelled by expired surgeons. The new scan is then compared to labelled brain (brain atlas) and automatically labelled and segmented. A hybrid method which is combination of threshold filters, CNNs and Brain Atlases is also researched for the same task. For trajectory calculation part a series of numeric and optimization algorithms are researched. The final trajectory suggestions are calculated using optimizations algorithms due to constraints (Trajectory with minimal distance, trajectory best suited for the robot, safest trajectory). Fuzzy logic algorithms are also considered for trajectory calculation.

Expected scientific contribution

The research is expected to include the optimal position of the neurosurgery robot during the automatic brain biopsy surgery planning phase calculations. The planning strategies for biopsies in high risk brain areas with the use of neurosurgery robot will be researched and tested to include them in the automatic planning algorithm. The time reduction of the whole planning procedure will be measured and analyzed with the introduction of automatic planning algorithm.

Keywords

Robotics, medicine, medical scan analysis, robotic surgery planning, robotic surgery

Increasing the Efficiency of Corrosion Resistance of Products Made of Spot-Welded Steel Wires by Optimisation of Welding and Coating Parameters

PhD candidate: Anna Poropat
Mentor/s: Ivan Stojanović
Affiliation: Feroplast d.o.o. Buje, Croatia

Introduction

Wire products are common in a wide range of industries, so they need to have an adequate corrosion protection for each application such as construction machinery, furniture, refrigerators, ventilation, cooling and heating systems. Furthermore, when considering overall effect of corrosion protection processes, this phase of manufacturing has significant impact on the price because of material, amortisation, energy, the need for the employees and environment issues. Cost effective and economically viable solution is in coordinating the quality of the steel surface with pre-treatment and type of coatings. The most critical areas on wire products are cross spot welds. In order to ensure optimal corrosion protection and price it is crucial to examine the reason of corroding spot welds. Coating's main function is to ensure barrier between the metal substrate and the aggressive environment. Shape and surface properties of weld depends of welding parameters such as electrode force, squeeze time, weld time, hold time and weld current.

Aims

The main aim is to classify weld types (considering used parameters) and correlate them to adequate corrosion durability of welded joints. Also effect of coatings and layers of electro-static powder coatings on a specific weld type should be investigated. The aim is to offer confirmed combination of welding parameters and type of pre-treatment and coating (multi- or single-layered) for different requested durability. Also, it is useful to combine hangers designed to better coverage of the powder coating on the most critical areas of the product (cross spot welds, wire-sheet welds). The hangers could also be designed in a way that allows regeneration what should minimize the expense of the plant because currently each hanger must be discarded after 2 cycles. The most novel way in satisfying cost and to delay corrosion rates is classifying condition of the surface covering manufacturing phase (welding) and corrosion protection. This research is planned to contribute the possibility of specifying correct parameters of welding wires of same and different diameters so the weld quality is standardized. It is also planned to specify kind or combination of procedures in the plant for corrosion protection so it guarantees necessary lifetime for different products.

Methods

Advanced electrochemical methods should be applied for characterisation of powder coating. Scanning electron microscopy for micro-surface morphology on welds will be used. Certain industrial qualification tests will be performed to ensure suitability and durability (weld test, salt spray test, weld strength test, adhesion study, thermal stability, etc.).

Expected scientific contribution

Novelty which brings this research is in developing an algorithm that based on requested corrosion durability defines operational procedures in correlation with welding and corrosion protection for minimum cost. New cost-effective system of manufacture (welding) and coating could be developed. High-quality scientific results on parameters of welding and powder coating procedure should be obtained. Namely, weld classification regarding parameters and corrosion rate dependance on weld type will be examined.

Acknowledgments

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Keywords

Resistance spot weld, corrosion rate, powder coating

A Green Microwave – Assisted Synthesis of Nanocomposites Based on TiO2/Graphene Oxide for Visible Light-Induced Photocatalysis

PhD candidate: Camilo Sánchez Tobón
Mentor/s: Lidija Ćurković, Davor Ljubas
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

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 removal of OMPs due to its capacity to produce strong oxidizers 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. For these reasons, modification of TiO_2 with different elements such as metals, non-metals or adding carbon materials (like graphene oxide – GO) is the most common strategy that has used to reduce the recombination rate and/or shifting optical response of TiO_2 to the visible light range to produce an energetically efficient material that allows using solar energy for the removal of OMPs.

Aims

The main aim of this research is the microwave-assisted synthesis of nanocomposites based on TiO_2/GO photocatalysts with low band-gap energy and increased visible-light-driven photocatalytic activity, which could use solar energy efficiently for the removal or degradation of OMPs.

Methods

For TiO_2 synthesis, titanium (IV) isopropoxide (TTIP) as a titanium precursor will be used. The chemical molar ratio of reagents will not be evaluated. Instead, temperature and reaction time will be considered as crucial parameters for the microwave-assisted method. Morphological properties will be determined by X-Ray Diffraction analysis, Raman and FTIR spectroscopies. At the same time, the photocatalytic activity will be evaluated through the degradation of selected OMPs (e.g. the drug ciprofloxacin) using UV and visible light. The photoactivity of the synthesized materials will be compared with the commercial TiO_2 (Degussa P25).

Expected scientific contribution

In this research, it is expected to understand how temperature and reaction time determine morphological properties (e.g. crystallinity, specific surface area, porosity, etc.) of the synthesized materials by the microwave-assisted method. Subsequently, the influence of these morphological properties on the photocatalytic activity in the degradation and/or mineralization of OMPs will be explained. Additionally, it is expected that this non-conventional synthesis technology could produce homogeneous material in shorter reaction time with higher production yields, as well as to reduce the production's energy consumption significantly.

Acknowledgments

This research is the 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, TiO2 based composites, UV-Visible light photoactivity, organic micropollutants degradation.

Study of the Optimal Connection Between Water and Energy Systems

PhD candidate: Goran Stunjek
Mentor/s: Goran Krajačić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Water and energy are essential needs for normal function of modern society, so it is very important and challenging to provide secure, affordable and clean supply. In the 21st century, due to threats such as climate change and unstable geopolitical situations, the focus on secure supply is becoming even more crucial. The proposed field of research is based on previous research on the connection between water and energy systems, primarily on available commercial and/or open-source models, and data available from the actors involved in the water and energy systems. The main hypothesis of the work is that precise validation of modelling of complex water energy nexus will improve future planning of infrastructure through cost reduction and better integration of available renewable water and energy sources. It will also enable modelling of systems under extreme weather conditions caused by climate change and will allow for better planning and implementation of adaptation measures.

Aims

The objectives of the research include (i) validation of the model of complex connection between water and energy systems; (ii) improving planning and reducing the cost of building infrastructure; (iii) ensuring a more complete integration of available water and renewable energy sources; and (iv) modeling the effects of extreme weather conditions caused by climate change on energy and water systems. The aim is to show savings and/or reduction of the impacts of climate change on these sectors by applying computer modeling of different scenarios and compare the results of the model with the actual application of sensors and microgrid technology within the INSULAE project on the Island of Unije. The aim of the dual modeling approach is to show the advantages and disadvantages of each defined approach and to show the savings results of the application of different models of water and power systems management.

Methods

Two different approaches to the optimal operation of water and power systems will be studied. In the first approach, it will be assumed that all information that determines the significant economic and physical characteristics of both (connected) systems is available in one place – in the "central control unit". It is then possible to formulate the problem of economically optimal and secure water and energy supply as one centralized optimization problem. The objective function in this problem should reflect the economic well-being of the water and energy system. The second approach assumes that water and energy systems are managed in separate control centers. In order to achieve maximum social well-being, these two management centers must necessarily coordinate their actions. In the ideal situation, the coordination algorithms, and the algorithms of both control centers, will achieve the global optimum, i.e. the system will be able to be managed with the same benefits as in the abovementioned centralized approach.

Expected scientific contribution

Acknowledgments

Contributions from: CITIES project funded by the Danish Innovationsfonden, European Union's Horizon 2020 programme projects INSULAE and KeepWarm, and "Provision of electricity in the event of climate extremes and natural disasters" project from European Structural and Investment Fund are greatly acknowledged.

Keywords

Water-energy nexus, optimization, energy modeling, renewable energy sources, water management

Development of a New Loading System of the National Force Standard

PhD candidate: Daniel Pustički
Mentor/s: Željko Alar
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Force measurement is the basis for determining the mechanical properties of a material or product. Since machine parts are dimensioned based on those properties, they occupy a special place among other physical and chemical properties.

The measuring sequence of the force measurement tops at the primary force standard, which achieves the corresponding force by loading directly with weights. Today's measuring capability of such devices is 0.002%. As the Newton (N) force unit is a derived unit in the SI system, it follows that there is no international primary force standard, but there are primary force standards for a particular country or metrology area. The Republic of Croatia has no primary force standard machine with such measuring capability. The measuring sequence is maintained by the Laboratory for Testing Mechanical Properties of the Faculty of Mechanical Engineering and Naval Architecture, which is the holder of the state force standard with a measuring capability of 0.05%. As each country wants to improve its metrology infrastructure, there is a need for a force standard with a nominal value up to 1000 N with lower measurement capability that would improve the laboratory's as well as national metrology capabilities.

Aims

The objective of the research is the development of a new device with a loading system directly with weights (deadweight), as a primary force standard that will contribute to determining the source of uncertainty of the force measurement and quantifying individual impacts on measurement uncertainty. This will also enable a scientific assessment of the possibility of reducing the primary force standards measuring capability to the limit of 0.002% by introducing some new acknowledgments about materials and metrology.

Methods

The planned research methods are theoretical, experimental, and numerical. The theoretical phase consists of elaborating on the general construction of a deadweight machine, selection of materials, the machine's exact dimensions, and weight production technologies. The goal of the experimental phase is to make a deadweight machine and calculate its measurement uncertainty. The numerical phase would consist of determining the best measuring capability of the deadweight machine.

Expected scientific contribution

The expected contribution of the research is the development of a deadweight primary force standard, identification of the uncertainty sources, and assessment of their impact and quantification. Furthermore, the scientific judgment on the justification of improving certain segments of the force standard to improve measurement capability and development of a new force standard as a national standard.

Keywords

Force, mass, deadweight, measurement uncertainty, force standard

Optimization of Flapping-Wing Dynamics with Discrete Mechanics and Optimal Control

PhD candidate: Marko Kasalo

Mentor/s: Zdravko Terze

Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Insects are well-known for their impressive aerial capabilities and exceptional flying efficiency at very low Reynolds numbers [1]. Successfully realized insect-inspired unamnned aerial vehicle could efficiently hover, fly sideways and backwards, quickly change their direction and even land upside down. However, in order to preserve the favourable aerodynamic phenomena generated by the flapping-wings, such insect-inspired aircraft should be small in size. Due to limited dimensions flapping-wing aircrafts do not have the ability to store and carry large amounts of energy required for propulsion [2]. In order to achieve greater endurance or load carrying capacity, it is necessary to optimize energy consumption.

Aims

The aims of this research are the development and application of a new flapping-wing aircraft dynamics optimization method based on the discrete mechanics and optimal control approach.

Methods

Quasi-steady aerodynamic model [3] and discrete mechanics and optimal control (DMOC) approach [4] are combined, to reduce energy consumption by optimizing flapping-flight dynamics.

DMOC is directe transcription method for optimal control of mechanical systems [5]. Discretization of the Lagrange-d'Alembert principle results in the structure preserving variational integrator [4]. Structure preserving integrators are numerical methods for solving differential equations that preserve the inherent geometric dynamical structure of the mechanical system, resulting in faster and more accurate numerical integration [6]. Variational integrator is implemented as equality constraint when formulating an constrained nonlinear optimization problem. Such approach results in more accurate and faster optimization compared to conventional methods [4].

The quasi-steady aerodynamic model is based on the assumption that the aerodynamic forces are inherently time independent, therefore the aerodynamic forces are steady at each instant and every change of the aerodynamic forces in time follows from the direct time-dependence of kinematic variables [7]. The quasi-steady models, due to their good ratio of accuracy and computational efficiency, are well suited for optimization, sensitivity analysis, dynamic stability analysis, and control design [8].

Expected scientific contribution

A new flapping-wing dynamics optimization method based on the discrete mechanics and optimal control approach and numerical solutions of the corresponding finite-dimensional nonlinear optimal control problem.

Acknowledgments

This work has been fully supported by Croatian Science Foundation under the project IP-2016-06-6696.

Keywords

flapping-wing, discrete mechanics and optimal control, variational integrator, quasi-steady model

Biomass Gasification in a Drop Tube Furnace and Updraft Gasifier: Experiments and Numerical Modelling

PhD candidate: Damijan Cerinski
Mentor/s: Jakov Baleta, Mário Costa
Affiliation: University of Zagreb, Faculty of Metallurgy, Croatia

Introduction

Using biomass as an energy resource has advantages of wide distribution and availability of raw materials, and currently is one of four most common energy resources with a 10% share of total world primary energy. Biomass gasification is a thermochemical process of partial combustion which results in conversion of biomass into the syngas suitable for further energy conversions, especially for use in gas turbines, fuel cells and internal combustion engines. Operating parameters, such as mass flow of biomass, gasifying agent and also temperature and pressure of the reactor have a strong influence on the quality of produced syngas and desired gasification performance. In order to investigate the influence of separate operating parameters on the biomass gasification process which is needed for the development and optimization of gasifiers, mathematical models are developed which significantly reduce expensive and time-consuming experimental investigations.

Aims

The aim of this research was to develop a biomass gasification model based on kinetic models for pyrolysis and tar cracking processes in a combination with thermodynamic equilibrium modelling approach for describing reduction and combustion zones. The model was validated against experimental data from pilot-scale updraft gasifier from ENEA Trisaia research centre in Italy.

Methods

In this work, the gasification of almond shells in a pilot-scale updraft gasifier was modelled. To describe the pyrolysis behavior a Bio-Poli-Mi kinetic mechanism was used, along with applying two different tar cracking models. The gasification and combustion of char were modelled within the thermodynamic equilibrium model by calculating the minimization of Gibbs free energy.

Expected scientific contribution

Newly developed biomass gasification model based on the combination of thermodynamic equilibrium model and pyrolysis kinetic model. Validation of newly developed model through experimental measurements of a pilot-scale updraft gasifier.

Acknowledgments

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Keywords

Biomass gasification, pyrolysis kinetic model, tar cracking model, agricultural residue

Implementation of Model Predictive Control in Commercial Buildings

PhD candidate: Arlinda Bresa
Mentor/s: Tea Žakula
Affiliation: Faculty of Mechanical Engineering, University of Prishtina „Hasan Prishtina", Kosovo

Introduction

The exploiting of advanced technologies as a means to mitigate energy consumption in the building sector has gained increasing attention in recent years. The improvement of building energy performance can be tackled from a basic scale by implementing conventional energy efficiency measures, additionally, more advanced approaches have proven to be effective ways to enable energy savings in buildings, without compromising thermal comfort of the occupants. One of these promising technologies is the use of Model Predictive Control (MPC) as a control strategy for the Heating, Ventilation, and Air Conditioning (HVAC) system in buildings. The MPC controller is used to regulate the current control action for HVAC parameters via optimization algorithms, depending on weather prediction, thermal gains, occupancy, and other disturbances in the thermal zones. The embedded core part of the MPC controller is the prediction model, whose accuracy and robustness preconditions the accuracy of the MPC predictions. Hence, the model development for MPC is an important and a challenging task due to the complexity of the non-linear thermal dynamics of buildings. A plethora of model types have been developed to predict similar outcomes in different buildings for MPC, this variety has urged the need to find and extract the most efficient models and to address the singularity issue of the models. A real pilot building is used to model, test, and implement the MPC controller, while considering the thermal inertia of the building simultaneously and utilizing the thermal mass as a passive thermal storage.

Aims

The aim is the implementation of MPC models as an effort to set a threshold for application of this technology in real commercial buildings. The effect of this model-based control technology in the energy performance of the system is emphasized when considering the thermal mass of the building as a passive energy storage, that enables load shifting and reduction of peak energy demand.

Methods

Numerous mathematical models are going to be developed including physics based or white box models (using detailed TRNSYS model), and by using data analytics, data driven models or black box models (ANN, ARX, ARMAX, SVM, BJ, Fuzzy logic), and grey box models (thermal network, state space) will be modeled to describe the thermal behavior of the physical building. The model building and system identification is executed via MATLAB and TRNSYS software, and validated through on-site data measurements from the pilot commercial building.

Expected scientific contribution

The modeling, testing and implementation of model based predictive control in a real commercial building, by utilizing thermal mass as a passive thermal storage will aid to generalize the use of MPC controllers in the building sector. The singularity of the models will be addressed to enable the inter-building transfer of the control strategies between buildings with similar features.

Keywords

Model predictive control, model identification, passive thermal storage.

Influence of Afm Image Artefacts on Measurement Uncertainty Evaluation

PhD candidate: Andrej Razumić
Mentor/s: Biserka Runje
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Atomic force microscope (AFM) is a versatile and powerful tool for analysis of topographic properties, whose scanning resolution is equal to or less than 1 nm. AFM works on the principle of the transition of the sample surface by measuring the interaction between a sharp probe and the sample surface. It can be said that atomic force microscopy holds a significant place in the area of topographic images measurement as well as nanotechnology and surface science. Since AFM is a very complex system measurement results are affected by many factors. Therefore, the value of measurement uncertainty is unknown. Measurement uncertainty is defined as a parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand. Following this, the traceability in AFM image scanning cannot be achieved. Traceability is a property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty. This paper conducts an analysis of the influence of artefacts on measurement uncertainty in the area of topographic surface measurement.

Aims

The aim of the research is to explore how AFM artefacts affect the assessment of measurement uncertainty. The question arises as to the reliability of the measurement result. The result of AFM measurement is usually qualitative data (e.g. the result is a picture, not a real number), without a reliability parameter or an exact measurement uncertainty value. Therefore, the aim is to evaluate measurement uncertainty when the measurement result is qualitative data.

Methods

AFM artefacts can be caused by any part of the measurement system, including a deficient probe, scanner, computer image processing, vibration noise, surface contamination, etc. Any of these parts affect measurement uncertainty. To ensure traceability of results, knowledge of the value of measurement uncertainty is necessary. The first step in estimating measurement uncertainty involves identifying and classifying the AFM impact parameters. It is impossible to avoid the occurrence of AFM artefacts, but there is a way to reduce the impact of artefacts. Also, every AFM artefact discovered should be analyzed to prevent new artefacts occurrence. Reducing the AFM artefacts appearance leads to a decreasing number of inaccurate conclusions about the measured sample.

Expected scientific contribution

The expected scientific contribution is to determine, quantify, and minimize the impact of AFM image artefacts on the quality of measurement results.

Keywords

atomic force microscope (AFM), artefacts, measurement uncertainty, traceability

A Method for the Efficient Rational Design of Ship Structures

PhD candidate: Marin Palaversa
Mentor/s: Pero Prebeg, Zvonimir Bujanović
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Ship design has traditionally been based on simple formulae from classification societies' (CS) rules. The formulae, though leading to a design that satisfies all the CS requirements, cannot produce optimum design, i.e. one that fulfils design objectives in the best possible way while satisfying all the imposed requirements. Thus, a new design method, called the rational ship structural designed (RSSD), emerged in the 1970's. It is based on structural analysis by means of the finite element method (FEM), automatic structural evaluation that comprises CS rules and structural optimisation (SO). However, the SO includes hundreds or thousands of iterations and ship structural response must be obtained in each iteration. As the computational time and effort related to this are usually high, application of the RSSD is not be feasible within timeframe of a typical engineering design process if modifications are not introduced. The most computationally demanding stages are calculation of ship structural response and sensitivity analysis of its stiffness matrix. This can be overcome by means of suitable mathematical and programming techniques.

Aims

The goal of this thesis is to develop an efficient RSSD method by employing state-of-the-art technologies from mathematics and computer science. To achieve this, local surrogate modelling of structural adequacy is proposed, i.e. development of surrogate models in the vicinity of design points whose structural response is obtained by means of the FEM, efficient decomposition and differentiation of the stiffness matrix and parallelisation and vectorisation of suitable computational processes.

Methods

A numerical approach will be applied. State-of-the-art mathematical methods for matrix decomposition and differentiation will be evaluated from the standpoint of their use in the RSSD. A new module comprising structural sensitivity analysis will be developed and implemented in a FEM solver called OOFEM (Object-Oriented Finite Element Method). Subsequently, CS rules will be analysed and software for structural capability calculation will be developed. A new surrogate model of ship structural adequacy will be proposed and implemented in a software solution applicable to the single objective ship SO. Finally, a suitable SO method and algorithm will be selected and implemented in software for the efficient RSSD.

Expected scientific contribution

A new local surrogate model of ship structural adequacy based on sensitivity analysis of ship structural response and structural capability w.r.t its use in the single objective optimisation of ship structures will be developed. Sensitivity analysis' methods and matrix decomposition and differentiation methods suitable for application in the RSSD will be evaluated from the standpoint of their accuracy and efficiency. Computational processes suitable for parallelisation and/or vectorisation will be identified. The SO algorithms based on mathematical programming methods for application in the RSSD will be evaluated.

Keywords

Ship structures, structural design, structural optimisation, surrogate models, sensitivity analysis

Pyrolysis of Mixed Plastic Waste into Fuels

PhD candidate: Irma Kremer
Mentor/s: Daniel Rolph Schneider
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Disposal of plastic waste is becoming increasingly problematic in the world as well as in Croatia, where a large part of this material ends up in landfills or accumulates in a natural environment. Although the benefits of material recovery (recycling) are higher, not all the quantities of plastic waste can be recovered that way because of different technical, economic or ecological reasons. Post-consumer waste plastics that cannot be recycled represents a concerning environmental issue. According to the latest available data for Europe, as much as 25% of collected post-consumer waste plastics are landfilled, 43% is energy recovered and 32% is recycled. One of the possible ways of recovering non-recyclable plastics (landfilled) is pyrolysis, which is considered as environmentally friendly technology for obtaining fuel or chemicals from plastic waste.

Aims

The aims of this research:

- determination of the composition of non-recyclable plastics and optimization of the pyrolysis/catalytic pyrolysis process to get the high-quality products based on the real composition of generated waste plastics.
- simulation of the pyrolysis process.
- potential pilot project in cooperation with the waste management company.

Methods

The methods of the research:

- the composition of the non-recyclable plastics will be determined by collecting plastic waste samples from multiple waste management companies, sorting and identifying using analytical techniques (infrared spectroscopy). Experiments will be conducted using thermogravimetric analysis for small samples to determine thermochemical behaviour and kinetic parameters, which is required for understanding the mechanism of reaction and optimization of the pyrolysis process. Experiments with larger samples will be carried out in semi-continuous batch pyrolysis reactor.
- simulation of the pyrolysis process will be made by comparing the experimental data and mathematical model.
- potential pilot project will be made as the large-scale simulation of the investigated pyrolysis process.

Expected scientific contribution

Solving the issue of non-recyclable waste plastics by optimizing the pyrolysis/catalytic pyrolysis process

Acknowledgments

This work was has been fully supported by the Croatian Science Foundation under the project Neoplast (3200) – Smart energy carriers in the recovery of plastic waste.

Keywords

plastic waste, termo-chemical recycling, pyrolysis, chemical kinetics, mathematical modelling

APPROVED TOPIC

Techno-Economic Analysis and Capacity Optimisation of Solar and Wind Integration in Advanced Biogas Plant Operation

PhD candidate: Robert Bedoić
Mentor/s: Tomislav Pukšec, Lidija Čuček
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The use of cultivated energy crops for biogas production followed by the expiry of subsidies for electricity production in combined heat and power generation has slowed the growth of the biogas industry. Alternative operational policies, which include low-cost substrates and various biogas utilisation pathways has shown to be attractive to maintain biogas industry competitive energy source. The aim of this research is to evaluate the integration of solar and wind into a biogas plant operation to meet the energy demand to convert biogas into biomethane and e-methane.

Methods

The flexible energy production and operation in the advanced biogas plant model will be tested with linear programming using open source language Julia by which the capacity of wind, solar, gas storage, upgrading unit, electrolyser and methanator will be optimised to minimise the total annual cost. To determine what are the key factors in a feasible operation of the advanced biogas plant model, the techno-economic analysis will be carried out considering optimised capacities of studied units, market prices for electricity, the selling price of renewable methane and the feedstock gateway fee.

Case study: Biogas plant operates with a digester of ca. 3,900 m^3 capacity and post-digester of 1,900 m^3 capacity. Biogas produced at the plant is utilised in a gas engine of 1 MW of electrical power to produce electricity and heat which is used in a nearby rendering plant. According to the data obtained by the plant, the biogas production in digester is estimated on Q_f=300 Nm^3/h, with the average share of methane $x(CH_4)$=0.60.

Preliminary results

As the price of electricity on the day-ahead market increases the role of biogas storage in advanced biogas plant model becomes more important. Increasing the price by 50% increases the requirements for storage capacity by 72% for i=5%, while for i=10% the increase in storage capacity is 395%. The installation of biogas storage increases capacities of upgrading unit, electrolyser and methanator. For the electricity price of 8.87 €cent/kWh, the installation of ca. 2,500 m^3 of biogas storage increases the capacity of upgrading electrolyser and methanator capacity. The wind capacity ranges between 8.8 and 11.7 MW, while the PV capacity ranges between 2.7 and 3.9 MW.

Discussion

Results show that the location of the studied biogas plant has a higher potential to produce electricity for upgrading and methanation using wind energy than PV due to higher capacity factor. Installing biogas storage in the advanced biogas plant operation contributes to higher wind and lower PV penetration in the system. At the same time biogas storage increases the capacity of upgrading unit, electrolyser and methanator by 15-40%. Dynamic analysis of the advanced biogas plant model showed that the production of electricity from variable RES at the location can meet demand for a conversion of biogas into methane and hydrogen production.

Acknowledgments

The authors acknowledge the financial support from the Slovenia-Croatia bilateral project Interdisciplinary Research on Variable Renewable Energy Source and Biomass in Clean and Circular Economy (BIOVARES).

Keywords

Food waste, biogas upgrading, methane, renewable electricity, optimisation

Development of a New Alloying System for Tool Steels Based on Thermodynamic Parameters

PhD candidate: Sandra Brajčinović
Mentor/s: Anita Begić Hadžipašić, Jožef Medved
Affiliation: University of Zagreb, Faculty of Metallurgy, Croatia

Introduction

In industrial plants, the use of tools is becoming more prevalent. Tool steels are most often exposed to high or elevated temperatures, and subjected to various loading and wear processes, and they are required maximum durability with minimal maintenance. Due to their exceptional strength, tool steels are well adapted for making high-pressure die-casting molds, various impact tools, and they also produce turning blades and cutting tools such as drills, blades and saw blades. Therefore, it is very important to achieve their structural stability and good mechanical and corrosion properties.

Methods

The selection and proportion of elements will represent an innovative approach to the design of tool steels with improved properties. Modeling the chemical composition and correlating it to thermodynamic and process parameters will determine the solidification sequence and the final microstructure, resulting in the production of tool steel with improved mechanical, tribological and corrosion properties. The selection of the appropriate chemical composition will be based on the calculation of equilibrium / non-equilibrium property diagrams (CALPHAD) with Thermo-Calc software support. After selecting the appropriate chemical composition, re-melting and synthesis of structural alloy melt will be initiated. During re-melting and synthesis, a simple thermal analysis will be used to determine the change in material's temperature with the cooling time. The microstructure of the synthesized alloys will identify the using metallographic analysis. The corrosion potential determination method Ecorr, electrochemical impedance spectroscopy (EIS) and Tafel extrapolation method will be used to obtain corrosion behavior data.

Preliminary results

The recent preliminary research was conducted on the HTCS-130 and Dievar tool steel intended for hot work. The Thermo-Calc program was used for the purpose of monitoring the thermodynamic equilibrium at all temperatures during the solidification process. According to the aforementioned models, phase diagrams have been designed, showing the elimination of specific phases at particular temperatures. Based on the phase diagrams obtained, the temperature stability areas were monitored for a specific phase, as well as the change in the concentration of a particular phase. By the electrochemical measurements corrosion resistance of HTCS-130 and Dievar tool steel for hot work of in medium of Lenox Band-Ade emulsion, water and 3.5% NaCl was investigated.

Discussion

The potentiodynamic polarization of the tool steel in the Lenox Band-Ade emulsion medium has resulted in a low corrosion rate relative to the water medium and 3.5% NaCl, where the corrosion rate was significantly higher. The metallographic analysis of the tool steel exposed to the Lenox Band-Ade emulsion medium showed no microstructural changes. However, corrosion products on the surface of the tested tool steel were observed in the medium of water and chloride media.

Acknowledgments

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Keywords

Tool steels, metallurgical processes, thermodynamics, corrosion, microstructure

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

PhD candidate: Dalibor Vidèrščak
Mentor/s: Zdravko Schauperl, Matjaž Godec
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Additive manufacturing (AM) techniques, like Selective Laser Melting (SLM), can directly manufacture alloys with highly complex geometric by melting the metallic powder layer by layer. Selective laser melting is suitably for manufacturing dental prosthodontic appliances and general for metallic biomedical implants. Due to the excellent mechanical properties and high wear and corrosion resistance, Co-Cr powders have been used in AM SLM manufacturing of dental prosthodontic appliances.

Methods

Proportional specimens were made from commercially obtained Co-Cr powder using Selective Laser Melting techniques on machines from three different manufacturers, applying the producer-recommended CAD design and SLM production parameters of the process. Samples were heat-treated after SLM production, according to the producer recommended heat treatment processes. Specimens were used for the static tensile test (tensile strength Rm and elongation ε), three-point bending (flexural strength RfM), and toughness test (toughness Ecu). Light and SEM analysis of microstructure were performed on the same specimens, and the hardness (HV0,2) measurements on the cross and longitudinal sections were performed.

Preliminary results

Preliminary investigations have been conducted on proportional specimens made from the commercial dental Co-Cr powder using SLM machines from different manufacturers, applying the recommended parameters of the process. Although the specimens were made from the commercial dental Co-Cr material, with the same technique (SLM), and with the recommended design parameters of manufacturers, significant differences in the microstructure and in the mechanical properties of the consolidated materials were observed (tensile strength, bending strength and toughness). The quality of products is very much influenced by the parameters of the AM SLM process.

Discussion

The Co-Cr dental alloy consists in the microstructure, mainly high-temperature γ-phase (FCC lattice) with carbides that are contributing to the increasing of mechanical properties, and room-temperature ε-phase (HCP lattice) which contribute to the corrosion and wear resistance (tribological properties) of alloy. Co-Cr dental alloy properties depend on the γ-ε (FCC-HCP) ratio. A higher proportion of the γ-phase (FCC) results in better mechanical properties, while a higher proportion of the ε-phase (HCP) results in better tribological properties. Also, the alloy properties depend on the type, quantity, and distribution of carbides in the microstructure of the alloy. From this, it can be concluded that correlating the AM SLM processing parameters with the structure and properties of the product and their various interaction require considerable development.

Keywords

SLM, Co-Cr dental alloy, microstructure, mechanical properties

Analysis of City Bus Driving Cycle Features for the Purpose of Multidimensional Driving Cycle Synthesis

PhD candidate: Jakov Topić
Mentor/s: Joško Deur
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Driving cycles are typically used for estimation of vehicle fuel/energy consumption and CO_2 emissions. As a part of wider research of multidimensional driving cycle synthesis, this research focuses on analysis of a broad city bus driving cycle dataset recorded in the city of Dubrovnik. The analysis is aimed at revealing the impact of road slope on velocity and acceleration distributions, and clustering the recorded data into several groups reflecting various driving and traffic congestion characteristics. Finally, the Markov chain method is employed to synthesize 3D driving cycles for the selected data clusters. The synthesized cycles are validated to ensure their representativeness in terms of faithful description of main features of the recorded driving cycles.

Methods

The driving data were continuously collected for a city bus fleet operating in the city of Dubrovnik over one-year period. The road slope profiles were reconstructed by using regression technique based on Gaussian processes. In order to reveal appropriate way of calculating joint conditional probability distribution over considered input variables (i.e. velocity, acceleration, and road slope), comprehensive analysis of individual input variables and their mutual correlations is conducted. Additionally, in order to analyze daily and seasonal variations in driving characteristics, the recorded driving data are clustered by using k-means algorithm into three distinctive groups. Finally, a procedure of multidimensional driving cycle synthesis based on Markov chains is outlined and examined.

Preliminary results

The correlation analysis has pointed out that the road slope has considerable impact on vehicle acceleration vs. velocity distribution, implying that the synthesis of 3D driving cycle should be performed jointly with respect to velocity, acceleration, and road slope states. Additionally, it has been shown that daily variation effects in terms of buses mean velocity and number of stops per kilometer are more emphasized than the seasonal ones for the particular city bus fleet. The results related to driving cycle synthesis has shown that features of validated synthetic driving cycles group around average values of recorded driving cycles, so that they can be considered as statistically representative in average sense.

Discussion

The research has presented a comprehensive analysis of recorded city bus driving cycle characteristics, which are relevant from the perspective of driving cycle synthesis. The synthetic driving cycles generated for each cluster have been validated with respect to a number of features that needs to well align with the corresponding features of recorded driving cycles. The future work is directed towards applying thus validated driving cycles in designing and optimizing advanced energy management control strategy for plug-in hybrid electric vehicles.

Acknowledgments

It is gratefully acknowledged that this work has been done within the project ACHIEVE ("Adaptive and Predictive Control of Plug-in Hybrid Electric Vehicles"; web site: http://achieve.fsb.hr/), supported by the Croatian Science Foundation under the Grant agreement No. IP-2018-01-8323. In addition, the research work of the first author has been supported by the European Regional Development Fund under the grant KK.01.1.1.01.0009 (DATACROSS).

Keywords

Driving cycle, synthesis, city bus, analysis

Numerical and Experimental Approach to Reduction of the Stagnation Temperature in a Polymer Solar Collector

PhD candidate: Borjan Ranilović
Mentor/s: Damir Dović
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The temperature of stagnation is the temperature reached by a solar collector under peak sollar radiation and a lack of flow through the collector. A lack of flow through the collector generally occurs when there is no demand for heating of the tank and the pump is turned off, but may also be caused by a malfunction. This temperature is known to be very high in most collectors and the temperature of stagnation normally exceedes the glass transition temperature of so-called comoddity plastics, which is the usual name given to mass produced polymeric materials. Due to this the use of such materials in collector design has not been possible and the price of collectors has remained relatively high compared to a potential collector made out of these polymeric materials. Despite previous attempts, a satisfactory solution has not been achieved since the proposed collectors either use special polymer materials which drive the price of the collector up or require active overheating protection.

Methods

Building on previous years' research, additional optical simulations and experimental measurements were performed. The final material selection has been made, and the initial prototype extrusion has been performed. Properties of polymer materials were researched in order to determine their long-term behavior. A PLC system was designed and will soon be tested along with the prototype system.

Preliminary results

There were difficulties in achieving the desired base optical properties of the materials, primarily the necessry transparency. The optical system has showed promising results, though the production precision in the initial prototype extrusion was not entirely satisfactory. The material properties and the CFD model are likely reliable, though final validation will have to wait until a full load test is performed later in the year. The planned measurements and final prototype production were unfortunately delayed by the pandemic.

Discussion

So far the results seem to support the hypothesis that a combination of overheating measures can be used to cost effectively limit the temperature of stagnation in polymer solar collectors. However, a full size prototype test still needs to be performed and the behavior of the collector under load evaluated. It will also be important to refine the production process for the final prototype to achieve the desired material properties and precision.

Keywords

solar, overheating, collector

Spatial Heat Demand Mapping Methods in Developing Countries

PhD candidate: Drilon Meha
Mentor/s: Neven Duić
Affiliation: Faculty of Mechanical Engineering, University of Prishtina „Hasan Prishtina", Kosovo

Introduction

Spatial heat demand distribution is crucial importance when it comes to the planning of low carbon energy systems. A lot of studies have proved that power to heat technologies in district heating are one of the most economically viable solutions for decarbonization of energy systems, compared with other alternatives that do not include heating sector into account. In this regard, spatial analysis district heating potential assessment using Geographical System Information tool (GIS) is needed both at the regional and local level. The identification and spatial distribution of heat demand for space heating are of significant importance for the planning and design of district heating systems because around 70-80% of total final energy consumption by the household sector is consumed for space heating purposes. Spatial heat demand mapping is especially of high interest for area location with cold climate, where the thermal energy used for space heating and water preparation is the highest form of final energy consumed by end-users.

Aims

The main aim of this paper is to assess spatial heat demand distribution mapping in developing countries respectively in small municipalities, urban areas and country-level using bottom-up and top-down heat mapping approach.

Methods

Top down and bottom-up mapping approaches are used for estimating city and country space heating demand. A top-down heat demand mapping method based on a GIS tool was used to assess the heat demand aggregated on 250 m × 250 m grids within a country and its municipalities. Such grids have provided information regarding the heat demand consumed annually in MWh by residential and commercial buildings. The method itself was based on country energy balances and population distribution densities. From the other hand, two bottom-up heat demand mapping case studies for respective urban areas in Kosovo are developed based on building features such as surface floor area, building height, building use and the share of the heated area. These mapping methods are based on a GIS analysis of heat demand with high spatial resolution grids.

Expected scientific contribution

The expected scientific contribution of this work is the estimation of heat demand spatially using a top-down heat demand mapping method suited for developing areas. The obtained results from this research are used for assessing the techno-economic feasibility analysis of district heating potential for the country as well as for municipality levels. This work was the basement stage for spatial district heating analysis and space heating demand reduction in buildings.

Keywords

heat demand, GIS, top-down, bottom-up, buildings.

Generic Method to Estimate Effectiveness of Mechanical Ventilation and Smoke Extraction Systems in Underground Car Parks

PhD candidate: Željko Špiljar
Mentor/s: Daniel Rolph Schneider
Affiliation: INVENTO PRO, Croatia

Introduction

Various ventilation systems are available for carbon monoxide and smoke extraction in case of fires in underground car parks, jet thrust fan systems, ducted ventilation systems and systems with extract fans. These systems depend not only on the rules applied during the design but also on the underground car park architecture. A generic method has been developed to determine the effectiveness of mechanical ventilation systems. The method evaluates a particular solution regardless of the chosen system type or the underground car park architecture. Research results demonstrate the benefits and limitations of various mechanical and smoke extraction systems in underground car parks. Potential for system improvement has been presented.

Methods

The methodology of the research consists of six phases, the literature review, the field survey, the case-studies review, numerical modelling, experimental methods respectively cold smoke tests to validate developed generic method, and finally, the analysis of the mechanical smoke extraction systems influence on the people during evacuation and fire-fighting interventions. Detailed literature overview and the analysis of the conducted data of the field survey and case studies review, were used to identify the different fire scenarios in underground car parks. That is the basis for the numerical modelling setup, primarily the initial and boundary conditions. To evaluate numerical modelling results, cold smoke tests were performed in underground car parks. Cold smoke test results were compared with the numerical modelling results to improve and calibrate the generic method. Finally, the results were used to analyze the influence of mechanical smoke extraction systems effectiveness on the people during evacuation and fire-fighting interventions in case of fire in the underground car park.

Preliminary results

Preliminary results show the developed generic method validated with cold smoke tests evaluates mechanical smoke extraction system effectiveness accurately, regardless of the underground car park architecture and chosen smoke extraction system.

Discussion

Although the developed generic method estimates mechanical ventilation and smoke extraction systems effectiveness in underground car park accurately, the method is highly dependent on the boundary and initial conditions. Furthermore, cold smoke tests are not identical to an actual condition in case of fire. Therefore, the additional comparison between the realistic fire incidents and generic method results will be made.

Keywords

numerical modelling, underground car park, mechanical smoke extraction system, extraction efficiency

Influence of Dimensional Accuracy and Tooth Flank Surface Texture on Worm Wheel Pitting Formation

PhD candidate: Robert Mašović
Mentor/s: Dragan Žeželj
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Worm gears are one of the most commonly used machine elements for power and motion transmission, where high transmission ratio in one reduction stage is required. Design and worm gear pair kinematics is characterized by dominant sliding motion between teeth flanks during gear meshing, unfavorable conditions for oil film forming and high contact pressure which result in tooth flank damaging. Worm wheel tooth flank is usually affected by scuffing and pitting as most common damage mechanisms. Studies concerning worm wheel dimensional accuracy as an influencing factor on pitting formation have not been conducted yet. Considering worm wheel dimensional accuracy, maximum contact stress locations on the worm wheel tooth flank which initiate pitting will be predicted. Surface texturing and its influence on the properties of contacts and tribo-conditions is a topic of many researches nowadays. Surfaces are usually textured by dimple-like geometry employing various patterns. Textures may fulfil three significant roles: debris trap, lubricant reservoir and micro-hydrodynamic bearing. Surface texturing results in temperature decrease and friction reduction However, the application of textured surfaces is not thoroughly studied yet, especially in gear applications. Therefore, surface texturing of the worm or worm wheel tooth flank will be carried out to investigate its influence on oil film-forming and lubricating conditions in worm gears.

Methods

Worm gear pairs used in the experimental study are made from 16MnCr5/CuSn12 and 16MnCr5/AlSn6 material. Manufactured worm wheels are optically 3D scanned and compared to the reference model. Dimensional accuracy analysis is conducted by measuring dimensions such as gear pitch error and rotational accuracy in radial and axial direction. Selection of the worm screw or worm wheel tooth flank surface texturing method was carried out and model testing will be carried out to verify the selected surface texturing method. Current focus is put on electropolishing of hardened steel which is commonly used as worm screw material. Initial electropolishing bath was a mixture of phosphoric acid, sulfuric acid and water.

Preliminary results

Dimensional analysis was conducted on 3D scanned models of worm wheels. It was found that gear pitch error is in range of ± 40 μm. As a result of electropolishing, produced surfaces have many pores and shallow dimples which should encourage creation of oil film and consequently improve pitting durability. Wear rate and pitting formation in tribological pair steel (16MnCr5, electropolished)-bronze (CuSn12) will be focus point of upcoming model testing.

Discussion

Vigorous electropolishing (high current density accompanied with long electropolishing time) produces shallow dimples on the surface of the part. Such texture has proven to be effective in reducing friction and improving pitting durability in common gear steel pairs. However, there is no studies for steel-bronze pair commonly found in worm gears. Surface texturing could result in decreasing bronze wheel wear rate as well as improving its pitting durability due to better oil film formation.

Keywords

Worm gears, dimensional accuracy, pitting formation, surface texturing

Segment-to-Segment Algorithm for Finite Volume Mechanical Contact Simulations

PhD candidate: Ivan Batistić
Mentor/s: Željko Tuković
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Contact problems are highly non-linear, mainly due to the contact constraints and unknown contact area, whereas numerical modelling of contact problems usually includes other non-linear phenomena, such as lubrication, wear, large deformation, heat transfer, etc. The Finite Volume Method (FVM) is capable of resolving such highly non-linear multi-physics problems as its development is based on solving the highly non-linear problems in the field of fluid mechanics. The recent developments of the FVM in the field of solid mechanics require the development of the contact algorithms to solve complex stress analysis problems. In this study, a new segment-to-segment method is proposed for the calculation of the normal contact force. The inspiration for such an approach is based on the segment-to-segment contact formulation commonly used in the Finite Element contact algorithms. The implementation will allow for the calculation of mechanical contact on the arbitrary unstructured meshes and large deformation of contacted bodies.

Methods

In the proposed segment-to-segment method contact boundary is treated like solution dependent Neumann boundary condition, which is explicitly updated within segregated solution framework. Calculation of the contact force is based on the penalty method. In the existing contact algorithm, penetration is calculated at mesh points on the slave patch, whereas in the current method penetration is calculated in an integral manner. It is expected that such an approach will increase the robustness and accuracy of the overall numerical model. Normal contact force calculation using the segment-to-segment method is a last step in the overall contact algorithm. The main part of the contact algorithm is contact detection, which can be divided into two parts, i.e. local and global contact detection. Global contact detection is performed at least once per time step in order to find all possible contact pairs. Such a test is performed using bounding boxes where every contact face is placed inside bounding volume and contact between bounding volumes is performed. The task of the local contact detection is to eliminate false contact pairs obtained by global detection and to calculate the integral value of penetration for every master and slave face, respectively. The computer code is implemented in the numerical package for metal forming simulations, which is based on OpenFOAM® software. The package is developed in collaboration between Bekaert, UCD Dublin and UNIZAG FSB.

Preliminary results

The results of the implemented segment-to-segment method are compared with the Finite Element results from the literature and with available analytical solutions. Numerical examples cover 2D and 3D contact problems with large and finite sliding.

Discussion

The implemented segment-to-segment method shows very good agreement with the Finite Element results, as well with the available analytical solutions. The method is available to accurately predict contact stresses for large and finite sliding problems , as well as large deformation of contacted bodies. The implementation also allows for using a non-conforming discretization of the contact interface. Future development of the proposed method will be based on friction calculation.

Acknowledgments

This research is supported by grant from the NV Bekaert SA, Belgium.

Keywords

segment-to-segment, mechanichal contact, Finite Volume Method, OpenFOAM

Modelling and Optimal Control of a Parallel Plug-In Hybrid Electric Vehicle

PhD candidate: Jure Soldo
Mentor/s: Joško Deur
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The thesis proposes an extension of a Plug-In Hybrid Electric Vehicles (PHEV) powertrain backward model with a sub-model describing realistic transient effects while maintaining computationally efficient quasi-static structure. The extended backward model will be used to develop an optimal PHEV powertrain control strategy that considers powertrain transient effects. The control strategy will also be extended by an algorithm that generates an optimal profile of battery state-of-charge (SoC) reference trajectory considering varying road grade and the presence of low emission zones.

Methods

Powertrain characteristics of a PHEV with parallel configuration can be described by the computationally efficient quasi-static (backward) vehicle model while the dynamical behaviour of PHEV powertrain can be described by more computationally demanding and more precise dynamical (forward) vehicle model. The effects of PHEV powertrain transients in terms of fuel and SoC consumption can be modelled with an appropriate static model based on the results of extensive forward model simulations. An expanded backward model is proposed which will include powertrain transient effects during gear shift and engine switching on/off events with the aim to reduce computational load while maintaining precision of a forward model. The insights gained from extended backward model simulation will be used for control strategy synthesis which will consider previously modelled transient effects with the aim of minimising energy consumption while maintaining acceptable levels of driving comfort and battery degradation. Optimal powertrain control variables obtained by the dynamic programming optimisation algorithm can also be used for synthesis of an optimal battery SoC reference trajectory used by the control strategy in the cases of blended operating regime, varying road grade and presence of low emission zones.

Preliminary results

The method for SoC reference synthesis in the case varying road grade and low emission zones for blended regime has been proposed and verified. Method for developing a backward powertrain model extended by the sub-model describing realistic transient effects is developed and tested.

Discussion

The thesis is expected to result in: (i) computationally efficient backward PHEV model which includes effects of powertrain transients described by the static regression model, (ii) optimal energy management control strategy which will achieve additional fuel savings and driving comfort by taking powertrain transient effects into account and (iii) reference SoC trajectory synthesis in the case of varying road grade and low emission zones for the blended operating regime.

Acknowledgments

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Keywords

Control, energy management, optimal battery state-of-charge, plug-in hybrid electric vehicle, expanded backward model

Integrated Approach for Energy Planning of Smart Islands

PhD candidate: Marko Mimica
Mentor/s: Goran Krajačić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Energy planning of islands and integration of smart technology on islands has been underlined as one of the priorities by the European Union. This is because the islands are most vulnerable to climate changes, but they also represent excellent locations for testing new technology.

Methods

This study presents a novel, integrated approach for energy planning of smart islands. The approach is divided in three main parts: Quantitative mapping of islands needs and resources; automatic energy planning scenario generation; and risk assessment of generated scenarios. In the first step, 40 indicators are defined for mapping of islands needs, resources, energy and telecommunication infrastructure and water resources and infrastructure. In the second step, indicators are used as input data to a novel Smart islands method that defines all possible technologies that can be installed on an island by matching islands' needs and resources, after which optimization process is conducted for defining different scenarios and quantity of technology. Finally, a novel risk assessment method is applied to all scenarios in order to determine the risk level for all scenarios.

Preliminary results

Presented approach clearly shows that, based on islands' local needs and resources, it is possible to determine type and quantity of each technology that should be installed on an island to achieve fully renewable energy system with precisely defined risk level of each technology.

Discussion

Presented approach can be beneficial for many different stakeholders including local government, citizens and investors in renewable energy and smart technology searching for markets to invest in. Future research will be assessment of replication possibilities of solutions implemented on islands to the mainland, particularly rural areas on the mainland.

Acknowledgments

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Keywords

Energy planning, Smart islands, Renewable power generation, Risk assessment, Energy system modelling

Windage Power Loss of Salient Pole Generators

PhD candidate: Siniša Majer
Mentor/s: Željko Tuković
Affiliation: KONČAR – Electrical engineering institute, Croatia

Introduction

The windage loss of the salient pole generators is a total power taken from the turbine shaft needed to establish air circulation necessary to transfer the heat out of the generator. Accurate analytical windage loss prediction is important but also a challenging task. Today's methods for windage loss calculation are based on simple semi-empirical formulas for drag of rotating cylinder and discs. Standard textbook moment coefficients are further expanded with empirical correlations that encompass the specifics of the salient poles generators like ventilation type, number of poles, airflow, and other flow features. These correlations are usually based on statistical analysis of the measured data on earlier built machines. Deviation of the calculated and measured windage loss can be as large as 100%, depending on the departure of the actual machine design from the one according to which the correlation for the moment coefficient was obtained. In focus of this research are improvement and generalization of the existing analytical method for windage loss calculation.

Methods

The research is based on a series of CFD simulations of air flow through the different types of salient poles generators. A set of calculated data is used for aerodynamic analysis of the influence of rotor structural components on the generation of the windage loss. Validation of the CFD models is based upon experimental data from a set of built and tested generators. In continuation of the research a set of numerical factorial experiments will be conducted and gathered data will be used to further examine the significance and interaction of rotor parts on windage loss generation.

Preliminary results

Validation of the CFD models show good agreement with experiments. Contribution of the rotor structural components is distinguished, and some interesting interactions are observed. The poles are recognized as one of the most important elements in windage loss generation. The existence of a tangential air velocity component in front of the fan inlet has been observed.

Discussion

The existence of a tangential velocity component changes the usual assumption of fan radial inlet and affects the assumed energy conversion in the fan. This influence the calculated airflow through the generator and consequently calculated windage loss. Similarly, tangential component of the velocity behind the fan affects the conditions in front of the entrance in interpolar space and thus amount of the windage loss produced by salient poles.

Acknowledgments

This research is supported by KONČAR Generators and motors Inc.

Keywords

salient pole generator, windage loss, analytical calculation, computational fluid dynamics

Corrosion Properties of Aluminium Alloys in Chloride Media

PhD candidate: Lea Lokas
Mentor/s: Vesna Alar
Affiliation: Competence Center AluTech, Croatia

Introduction

The global development trends are increasingly focused on the development of aluminium alloy constructions, due to their reliable mechanical properties, lightweight and good corrosion resistance in neutral media. Untreated surface of Al-alloy exposed to air or water will oxidize immediately which result in formation of non-uniform thin oxide layer. In aqueous environment such as seawater, with high concentration of chloride ions, breakdown of protective oxide layer occurs and these alloys are prone to localized corrosion that can cause structural damage. The increasing demand in the marine industry to lower the fuel consumption and to have a higher speed of the vessel has emphasized the importance of lightweight structural materials, like AA5xxx and AA6xxx, that possess a good combination of material property requirement. The aim of this work is to investigate and evaluate the effect of different concentrations of chloride ions, temperature and fluid flow on electrochemical potential, rate and various forms of corrosion on aluminium alloys 5xxx and 6xxx series. Based on the results of this research protection measures will be proposed to extend exploitation life of aluminium constructions in marine environment.

Methods

Investigation will be carried out in simulated laboratory and real field conditions on two aluminium alloys AA5083 and AA6060 that have application in marine environment. Field corrosion tests will be conducted in real-time marine environment for a period of one year. The tests will be performed on samples of aluminium alloys immersed partially and completely in seawater. Laboratory tests will include different DC and AC electrochemical methods under stagnant and flow conditions such as monitoring of open circuit potential, linear polarisation, potentiodynamic polarization, cyclic polarisation and electrochemical impedance spectroscopy. Furthermore, gravimetric method will be used to calculate the corrosion rate. Metallographic examination of corroded samples will be performed using metallographic microscope and scanning electron microscope (SEM/EDS).

Preliminary results

Latest research in the field of aluminium corrosion were mainly focused on development and applying rare earth salts as inhibitors, their addition to improve corrosion resistance of sol-gel coatings, toxic chromate replacement and development of new chromium-free effective coatings. Preliminary laboratory researches on AA5083 and AA6060 indicates that increase in temperature and alloy microstructure (i.e. present precipitates on grain boundaries and intermetallic particles) have significant impact on corrosion occurrence.

Discussion

To understand localized corrosion attacks and properly design anticorrosion treatment of aluminium alloy in seawater, it is important to link all influential parameters such as salinity, temperature, seawater flow rate and microstructure effect on corrosion occurrence on aluminium alloy as well as to document their effect on corrosion properties. So far, for corrosion evaluation in laboratory research mainly artificial seawater with different salinity was used. Therefore, the aim of the following work is to get results as realistic as possible by using freshly sampled natural brackish and seawater and compare results with field corrosion test.

Keywords

aluminium alloys, brackish water, seawater, corrosion

A Numerically Efficient Computational Model of a Flapping Micro Aerial Vehicle Based on Hamiltonian Geometric Reductions

PhD candidate: Viktor Pandža
Mentor/s: Zdravko Terze
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Unmanned aerial vehicles (UAVs) have already become a standard tool for a wide range of applications. Both quadrotor and fixed-wing configurations of UAVs are available on the market and both configurations are already in commercial use. Quad-rotor UAVs are popular for their hovering capabilities, vertical take-off and landing (VTOL), affordability and great maneuverability. However, these advantages come at a price of low efficiency and high noise. On the other hand, fixed-wing aircrafts lack hovering and VTOL capabilities, but exhibit much better efficiency. However, neither configuration scales well to small sizes. In short, there is no available flying configuration that satisfies requirements on small size, low noise, high energy efficiency, high maneuverability and VTOL. Therefore, researchers have recently focused on nature to seek solutions to the problem of flying at small size. The intuition is to focus on insects since they are able to accomplish all these requirements. They accomplish this by flapping their wings at high frequencies with complex wing motion, creating vortices at both leading and trailing edge of the wing, and using those vortices for lift and propulsion. However, as soon as it was discovered how insects fly, it was obvious that it will be a difficult task to design a manmade object that will mimic this behavior. One of the main difficulties is understanding all important aerodynamic phenomena that insects use for flying, and first step to better understanding is better computational model of the insect-fluid system.

Methods

The main tool for developing an efficient FSI model are reductions of the coupled fluid-solid system, arising from geometry mechanics. By using these reductions, it is possible to develop a monolithic solver, by reducing out fluid variables. The reduced FSI model will be supplemented with the mechanisms for describing vorticity effects.

Preliminary results

Fluid surrounding the flapping wings naturally resists the flapping motion of the wings, and the forces exerted on the wings by this phenomenon can be interpreted as the added mass that the wings have to accelerate and decelerate. Due to the high values of flapping frequencies, the insect-type flapping aerial vehicle exhibits high values of the added mass forces, that are important for the insect-type flight.

The preliminary results suggest that the added mass effects can be accurately and efficiently modeled within a monolithic flapping micro aerial computational model by performing Hamiltonian geometric reductions on a fluid-solid coupled system.

Discussion

Apart from the described added mass effects, the important viscous effects occur during the insect-type flapping flight in the form of the leading and trailing edger vortices. In order to capture these effects, a mechanism for modeling the shedding and evolution of the vortices, as well as the effects the vortices impose on the wings, will be implemented to supplement the developed monolithic computational model of the fluid-solid coupled system.

Acknowledgments

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Keywords

Fluid-structure interaction, Unmanned aerial vehicles, Geometric reduction, Efficient simulation

Applying Machine Learning Methods in Metrology

PhD candidate: Alen Bosnjakovic
Mentor/s: Biserka Runje
Affiliation: IMBiH, Bosnia and Herzegovina

Introduction

Traceable calibrations, harmonized treatment of measurement uncertainties, and industrial standards and guidelines are the significant components of the comprehensive metrological infrastructure that has enabled globalized manufacturing and international trade. All these facts are well known in the conventional metrology but with modernization and introducing digitalization in the metrology world. In line with that, it is necessary to establish new metrological infrastructure which reflects the actual industry needs. It supports the transition from the conventional metrology to the modern one by applying novel methods. This can be achieved by applying the machine learning methods in metrology.

Methods

The instrumentation of manufacturing environments with digital sensors usually leads to massive amounts of data. It requires reliable and automated data aggregation and decision-making processes to turn the data into useful information. The paper presents the steps of how data from different sensor networks can be applied and used for making conclusions and making decisions considering measurement uncertainty. In addition to this, the sensor networks comprise a range of process sensors for position, force, pressure, torque, etc. The paper demonstrates the essential elements of supervised machine learning methods such as regression and classification and data pre-processing, visualization, feature extraction, and feature selection and validation. We can conclude that measurement uncertainty is an indispensable factor for proper decision-making and risk assessment in the manufacturing processes. Finally, the decision-making process is determined by using big data analysis. The model for the reliable decision-making is given at the general level, and the model is implemented by using the appropriate computer programming environment.

Preliminary results

The results show that machine learning methods in metrology is applicable, and it can be used in the decision-making by using big data. In addition to this, the measurement uncertainty must be interpreted correctly, and data can be turned into useful information that can be us in the decision-making process.

Discussion

Two methods (classification, regression) are used and compared by each other on the same data sets. These methods provide promising results in the decision-making process, and it can be used in the decision-making process. The GUM documents and its supplements cover the uncertainty evaluation of the measurand quantities. The supplements can be found on the following webpage www.bipm.org. These supplements cover the Monte Carlo Method, and it will be studied further regarding the measurement uncertainty evaluation of selected aggregated and distributed data sets in sensor networks through computer programming environment.

Keywords

measurement uncertainty, machine learning methods, classification, regression, decision making

Model Predictive Control of a Passenger Cabin Heating and Air-Conditioning System of an Electric Vehicle

PhD candidate: Ivan Cvok
Mentor/s: Joško Deur
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Electric vehicle cabin heating and air-conditioning system is the highest energy consumer after the powertrain, and negatively affects the driving range. To increase the driving range in extreme weather conditions, new heating and cooling systems operating in the heat pump mode in addition to air-conditioning mode are designed, and use alternative cabin heating concepts such as infrared panels. Because these systems are equipped with redundant actuators and multiple energy flows, new control systems are necessary to achieve optimal vehicle performance. The aim of this research is to develop an optimal control system that coordinates multiple actuators taking into account their constraints and increases the driving range in extreme weather conditions while maintaining the passenger thermal comfort.

Methods

To obtain benchmark performance of a cabin heating and cooling system and gain insights in the optimal control, a dynamic programming-based control trajectory optimization is carried out first. Then, a practical control system is developed, which regulates the cabin air temperature and uses optimal allocation for setting the control inputs. Finally, advanced control system based on model predictive control is to be developed. The control systems will be implemented, calibrated and validated using detailed simulation environments. It is expected that the experiment-based validation will be carried out in cooperation with project partners.

Preliminary results

Control trajectory optimization results indicate that there is a possibility to set the trade-off between the passenger thermal comfort and energy consumption. The highest efficiency is achieved when the cabin temperature slowly reaches the target value. A hierarchical thermal comfort control strategy, including an optimised control input allocation algorithm, has been developed and compared with globally optimal control trajectory optimization results. The control strategy using on-line optimal allocation has been implemented for air-conditioning system and the verification results show that it is possible to tune the strategy for a favourable trade-off between thermal comfort and efficiency, and to achieve the behavior that is comparable to the globally optimal solution. Additionally, a control strategy using offline, genetic algorithm-based control allocation has been implemented in the heat pump mode with and without infrared heating panel control.

Discussion

Hierarchical control strategy with optimal allocation uses instantaneous optimization. Although its performance is qualitatively comparable to the benchmark, it is anticipated that the performance of control system will be further improved by using model predictive control, because it optimizes the control action on a prediction horizon and allows for incorporation of preview information.

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Keywords

model predictive control, electric vehicle, heating and cooling system, dynamic programming, optimal allocation

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