University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET

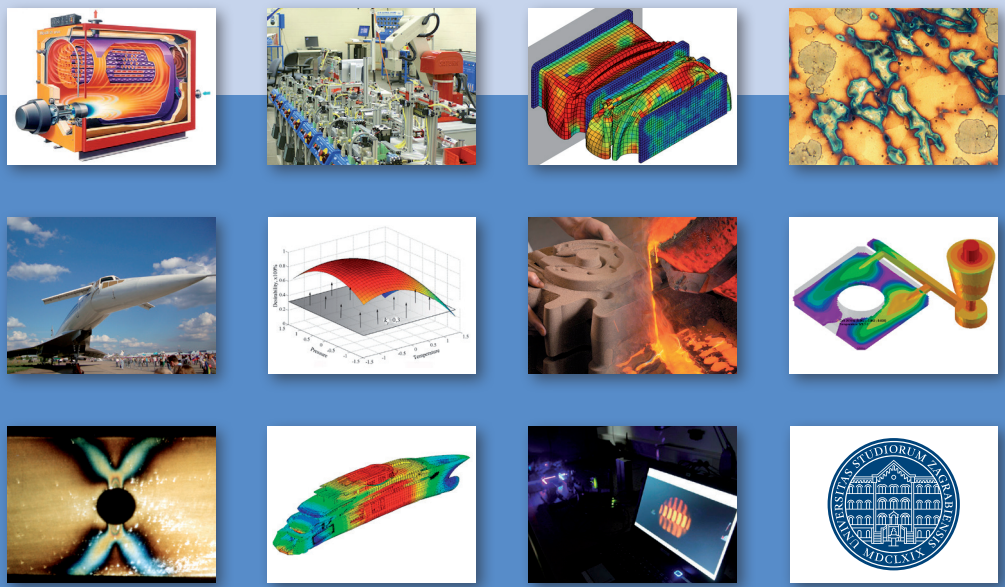
UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

Second Annual PhD Workshop

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

Book of Abstracts

July 1, 2016



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Preface

This booklet contains abstracts presented at the 2nd Annual PhD Workshop held at University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, on July 1, 2016. Annual PhD workshop is the integral part of PhD programme of Mechanical Engineering, Naval Architecture, Aeronautical Engineering and Metallurgical Engineering, launched on academic year 2014/15. PhD program is jointly developed by two faculties of University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy.

PhD workshop is aimed to provide forum for exchange of ideas among PhD students, to get most of PhD students at one place and to monitor progress of their PhD theses. Workshop should help students to strengthen their presentation skills and unify quality and transparency of PhD theses produced at different modules of PhD programme. 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 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.

17 participants on the PhD workshop presented preliminary topics of their theses, while 23 participants presented final PhD topics. Contributions collected in the booklet of abstracts are from different modules of the PhD study: Process and Energy Engineering (14 contributions), Computational Mechanics (6), Theory of Structures (5), Mechatronics and Robotics (4), Industrial Engineering and Management (3), Scientific Metrology in Mechanical Engineering (2), Aeronautical Engineering (2), Materials Engineering (2), Advanced Production Technologies (1) and Naval Architecture and Ocean Engineering (1). Diversity of these topics clearly indicates broad and rich research interests and activities at the Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy.

Editors

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PRELIMINARY PHD TOPICS

Towards Improvement of Dual Fuel Engines: Numerical Simulation of Fuel Slip and Knock Limits

PhD candidate: Mario Sremec

Mentor/s: Darko Kozarac

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Introduction

Diesel internal combustion engines are the most widely used in transport vehicles. Latest information of world energy consumption shows that the transport is the main source of exhaust gases. Because of environmental concerns, automotive industry is exploring alternative, more acceptable fuels. Compressed natural gas (CNG) is the cleanest fossil fuel and can be used in diesel engine with great benefits. Because of the low reactivity of CNG in Diesel engines it is usually used with so called Dual Fuel combustion (DF). Optimal parameters for DF engines are not yet investigated thoroughly which is the motivation for this work. Presented study shows improvement of disadvantages resulting from conversion diesel engine to dual fuel engine.

Aims

The main objective of investigation is to show influence of different injection timings and influence of knock phenomena on characteristics of port injected DF engine. Assumption is that is possible to decrease fuel slipping to exhaust port by changing the injection timing. The researching of knock phenomena in DF engine has the goal of finding the highest allowed compression ratio that will result in knock free operation.

Methods

For all numerical simulations the AVL Boost v2013 is used. The model is based on single cylinder stationary Hatz diesel engine installed in Laboratory of Internal Combustion Engines and Motor Vehicles on Faculty of Mechanical Engineering and Naval Architecture. The model is used to calculate the amount of fuel that slips into the exhaust port at different injection profiles and engine conditions. All numerical simulations are performed by using a mixture of methane and diesel fuel with 95% mole fraction of methane.

Expected scientific contribution

The model is used to calculate the amount of fuel that slips into the exhaust port at different injection profiles and engine conditions. By analyzing the results, the injection strategy that significantly decreases the CNG slip is defined. Additionally, by analysis of results with model for predicting knock occurrence, obtained at different compression ratios and engine conditions the highest possible compression ratio for the experimental engine is also defined.

Acknowledgments

This work is the part of FMENA project "Experimental Research, Optimization and Characterization of Piston Engine Operation with Dual-Fuel Combustion" funded by the Croatian Science Foundation. This help is gratefully appreciated.

Keywords

Dual Fuel, CNG, Knock, Injection timing, fuel slip

Managing Engineering Parameters in Complex Product Development Process

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Introduction

Users, which are mainly product designers and product developers, use computer aided design to design parts and assemblies. When they design complex product, they are dealing with many CAD models, parameters, constraints and relations. The eternal issues are how to manage complexity and how to help engineers to get final product fast and with less effort. A parameter in this approach describe a characteristic variable of a system element. The parameter can be of functional or geometrical character. Many parameters are related. For a complex product there can exist huge number of parameters. Therefore, many relations between these parameters exist. In order to reduce number of relations, parameters are grouped in functional groups or active chains. A parameter can be part of several active chains as well. Once a parameter changes it may affect any other parameter that is part of the active chain or even parameters in other active chains if the particular parameter is related to more than one active chain.

Aims

The aim of this research is to develop a system that would help engineers with management of engineering parameters. The system should track every change in parameters. Additionally, the system should have an ability to visualize relations which exist between existing parameters. The system also should have an option to import and export parameters as well as create new parameters. There are also several questions which need to be answered. Which model of communication will best suite chosen visualization model? How to treat non-geometric parameters? How to capture their value? How to visualize them? How system complexity impacts proposed system management and practical usage issues?

Methods

When dealing with complex products, there exist thousands, millions or even billions of parameters, depending how the product is complex. A Parameter could be functional parameters but mostly are geometrical. The best way to collect parameters is talking with engineers because they know which parameters are important and which not. A model should be made in order to understand how parameters are defined, where are they coming from, how they are related to each other and so on.

Expected scientific contribution

It is expected that this research would contribute product development research area as well as system engineering area. By answering these and many other research questions, the model for managing engineering parameters should be developed. Also, the model could help with communication between the owner of a parameter and all the people who that parameter is important.

Keywords

Complex product development, parameter management, traceability

ORC Microturbine with Optimal Partial Admission

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Introduction

Many mainstream industrial processes like cement, glass and chemical industry have large amounts of waste heat which is normally released into the environment. This heat may be used in a second plant / energy loop. This approach results in higher overall thermodynamic efficiency as well as economic benefits in the medium / long run. The cycle used in the second plant is known as Organic Rankine Cycle – ORC because it uses organic substance as working medium. Crucial part of the ORC is the expander with many types being currently evaluated, however the one of interest here – multi stage axial turbine, has very scarce info. Axial turbines researched so far have mostly been super-sonic single stage ones. Being small in size, these turbines, known as microturbines, include the partial steam feed / admission which complicates their modeling and flow.

Aims

The aim is to research the physics of flow within a partial admission turbine with an optimal admission degree in each stage ("blockades") and compare it to a turbine with a partial admission present only in the first stage.

Methods

Computational Fluid Dynamics – CFD is used to model and simulate the turbine flow. Microsoft Excel and REFPROP are used for turbine –thermo and – aero design, Gambit and MathCAD for flow space / blade modeling, and Ansys Fluent 16.0 for simulating and results postprocessing.

Expected scientific contribution

The contribution is at the field of microturbine design and numerical modeling; blades are designed using the 5th degree polynomial method. This work will show that special cases of microturbines may be designed, modeled and finally simulated in a CFD software. This is important since modeling a non-axis symmetric flow requires a different approach from modeling an axis-symmetric one, like in a full admission turbine. Analysis of varying blade number and width, comparison of analytical and simulation results, as well as aspects which may be perceived in a numerical simulation but cannot be known without building and testing a prototype including helical flow in the tubine, different results when using and not using blockades, presence of local swirls, local supersonic flow and power distribution per each rotor, will be provided.

Keywords

Organic Rankine Cycle – ORC, Turbomachinery, Microturbine, Partial Admission, Computational Fluid Dynamics – CFD.

Analysis of the Heat Exchanger Network Operation According to Entropy Generation Criterion

PhD candidate: Martina Rauch
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Introduction

Entropy generation and exergy destruction in heat exchangers relies on two simultaneous irreversible processes based on heat transfer between two streams with different temperatures and the existence of the pressure drop caused by the imposed fluid friction. Numerous recent scientific papers deal with the total entropy generation or total exergy destruction, thus making the entire heat exchanger the object of the analysis. Obtaining the minimal heat exchanger area, maximal heat flow rate and maximal entropy generation (exergy destruction) can be set as main goals of this analysis. This theoretical analysis would then be confirmed by designing an experimental heat exchanger capable of varying the fluid stream inlet on different positions of heat exchanger. For theoretically and experimentally confirmed operation of such heat exchanger (recuperator), according to given criteria, local entropy generation for all three connected heat exchangers will be presented for every examined situation. This research takes parallel flow and counterflow heat exchangers into account, for which analytical overview of local entropy generation is given, generated only because of the heat transfer upon final temperature differences between fluid streams. The reason for this is complexity of the defined problem and existence of numerous influential variables.

Aims

Fundamental objective of this research is determining the positions of the stream inlet for two additional heat exchangers needed to meet the following goals: minimal area of the heat exchanger, maximal rate of heat flow and maximal entropy generation. While first two cases are desirable, third case is not and therefore this operating regime, after meeting the third case criteria, should be avoided. For set objectives quantitative effect of the relevant variables defining the problem will be examined: mass flow rate of the additional exchangers and their inlet temperatures.

Methods

Based on theoretical elaboration of the model experimental device will be designed, which will then be used to verify theoretically obtained results: temperatures of all streams in such complex heat exchanger, for example. Theoretical and experimental model will allow the comparison of calculated and measured temperature values of all streams in the heat exchanger.

Expected scientific contribution

By examining available and recent scientific papers from the field of entropy (exergy) analysis of the heat exchanger, it can be concluded that those papers mainly deal with global level heat exchanger analysis, accepting only inlet and outlet fluid stream states. That approach cannot answer to the set demands, given as objective of this research. Answering those demands would be possible only if the problem would be dealt with on a local level, where the local heat exchanger area would be a significant local coordinate. Therefore elaboration of the algorithm for resolving the set problems, but on a local level, presents real scientific contribution for dealing with this kind of theoretical and practical problems.

Keywords

heat exchanger network, local and total entropy generation, optimal heat exchanger area, maximal heat flow rate, maximal entropy generation

Sustainability of Energy Recovery of Waste Under the Influence of Legislation Changes

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Introduction

One of the leading problems EU is faced with is waste. This problem is even more emphasised in urban areas. Increased population also increases energy consumption. This correlation make energy recovery (ER) of waste logical path towards sustainable development of the cities. At the same time waste represents resource that can alleviate, along with energy problems, material scarcity problem of EU through its material recovery (MR). Because of this EU has introduced waste hierarchy to divert produced waste from landfills to recovery processes. Also, EU set ER of waste to subordinated position to MR which decreases amount of waste for ER. In these circumstances question of sustainability of ER of waste comes in question.

Aims

The aim of this study is to answer to question of sustainability of ER of waste under the influence of legislation changes. Plan is to show sustainable degree of integration of ER of waste within the legislative framework.

Methods

Economic sustainability of waste-to-energy (WtE) cogeneration plant as a part of district heating system is conducted. Analysis is based on regression analysis carried over data for existing WtE plants and locally dependent data. Actual waste quantity and composition, socio-economic data and EU legislation framework are used as input for LCA-IWM prognostic model. Forecasted data are used to calculate internal rate of return of analysed scenarios. Scenarios are modelled to analyse combustion of local municipal solid waste alone, co-combustion of other local wastes and waste import from entire region. Environmental sustainability of different waste management systems (WMS) is evaluated through single-score assessment by primary energy return approach. This cumulative energy demand (CED) based approach reduce all external material and energy flows to PE equivalents which can be compared. Individual technology material and energy flows are constructed on the basis of life cycle inventory (LCI) process unit data. This way only internal waste flows that connect individual technologies are tracked through the whole analysed system. As the next step in this study, economic system optimisation using process network synthesis (PNS)is planned. This step is based on previously constructed technology UPR data which have to be expanded with economic data.

Expected scientific contribution

Expected result of this research is to benchmark sustainability of different scenarios of WMS in different fields (in this part of research in the fields of economy and ecology) and to give aggregated answer to a question of sustainability of integration of ER to WMS within the foreseeable legislation framework.

Acknowledgments

This work has been financially supported by the Croatian Science Foundation under grant No. DR-5-2014 (Career development of young researchers) and by the EU Intelligent Energy Europe project STRATEGO (grant agreement EE/13/650). This support is gratefully acknowledged.

Keywords

waste management system, energy recovery, material recovery, waste model, economic sustainability, environmental sustainability

Behaviour-Based Robot Using a Multi-Sensory Approach and Fuzzy Control

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Introduction

Obstacle avoidance is common issue in autonomous mobile robot control. There are many different approaches used to achieve better characteristic of obstacle avoidance behavior. Mobile robots, as a dynamic part of the environment, have to be able to avoid obstacles in real time. In this research a nonholonomic mobile robot is used. Nonholonomic robots by their genuine characteristic are incapable of lateral movement. This is a primary reason why, fundamental problem of navigation is even more expressed. Fundamental problem includes mobile robot motion planning and obstacle avoidance. Ever since the first research papers were published on the topic of obstacle avoidance, real-time architecture for obstacle avoidance and path planning for mobile robots, this still remains the field of increasing research interest due to its practical application.

Aims

Main goal is to achieve performance improvements in obstacle avoidance. The aim is to realize obstacle avoidance by means of combining different robot sensors. Sensor values will be processed using fuzzy logic controller in order to produce an accurate obstacle avoidance behavior. However, ultimate goal is development of robust algorithm for application in unstructured environment.

Methods

The starting point of this research is the hypothesis that significant improvements can be made in field of mobile robot motion planning if AI algorithms are combined with mathematical models that aren't considered yet in mobile robot navigation. Fuzzy control will be implemented due to a previous experience in the similar field. Fuzzy control has shown excellent results in mobile robot control and in combination with well specified behavior rules it is assumed that will result in excellent obstacle avoidance characteristics. Besides the mentioned AI method other approaches will be considered in order to increase performance and study their integration in one hybrid solution. Some of the methods are: Neural Networks, Genetic Algorithm, Adaptive Resonance Theory, Particle Swarm Optimization, etc. Research will be experimental and all algorithms will be tested in real environment. Mobile robot is equipped with range sensors and vision system, which will be used to enhance robot performance using algorithms for vision-based detection and classification.

Expected scientific contribution

Research should contribute to the field of mobile robot path planning and obstacle avoidance. There is intention of possible application in cluttered environments. We expect that research process will result in new behavior-based fuzzy control method for mobile robot navigation. Safety assurance in the presence of stationary and moving obstacles is important issue in mobile robot control so we expect to make a contribution in that field too. Developed algorithm should assure safety despite sensor and actuator uncertainty.

Acknowledgments

This research is supported by Klimaoprema d.d. In this research mobile robot eMIR (educational Mobile Intelligent Researcher) is used.

Keywords

Mobile robot, path-planning, obstacle avoidance, unstructured environment

Control and Energy Management Systems for Unmanned Aerial Vehicles (UAV)

PhD candidate: Matija Krznar
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Introduction

Since proper distribution of on-board battery energy is a particularly important factor of UAV flight performance and successful mission completion, an energy management system (EMS) needs to coordinate the battery power flow, and estimate the remaining available energy on-line to ensure favorable flight quality and endurance.In this respect, this research analyses various quadrotor design configurations and their impact on energy consumption. EMS-based estimates can be coupled with on-board sensors data and used within the UAV control strategy in order to maximize the remaining flight time, as well as to reduce response time during aggressive maneuvering and to achieve robustness to perturbations (air gusts).

Aims

In order to develop the proposed EMS and control algorithms, an upgrade to the current "hardware in the loop" (HIL) system is needed. This will include adding a complement of sensors feeding measurements from external sensors such as accelerometer, gyroscope, and barometric pressure sensor, which will be used for UAV state monitoring and feedback for the EMS and flight controller. Main goals of this research are the development of control and energy management algorithms that provides adaptive mission planning and multiple flight modes (different modes of flight control system operation) on demand.

Methods

The research is conducted using a mathematical model of different quadrotor configurations derived from kinematic and dynamic equations which are implemented as computer simulation models in Matlab/Simulink, Microsoft .Net framework and C++ for microcontrollers. Thus obtained simulation results are verified on the upgraded experimental setup featuring a hardware-in-the-loop (HIL) system suitable for half-aircraft dynamics emulation, and related optimization and design of energy management and flight control systems. After successful proof-of-concept, a full experimental model of quad rotor will be designed and constructed for the purpose of testing advanced control techniques combined with energy management controls.

Expected scientific contribution

Scientific contributions related to UAV power flow analysis for different flight missions are expected as a first step towards the design of energy management control system for the on-board battery, as well as the development of battery state-of-charge (SoC) and state-of-health (SoH) estimators. UAV state estimation based on sensor fusion and Kalman filtering approach is going to be investigated as a basis for the development of flight control systems based on appropriate optimization criteria combining flight duration, battery load and UAV state variance indices characterizing aggressive maneuvering and level flight robustness with respect to disturbances. Finally, research in brushless DC motor-based quadrotor servo-propulsor optimization and control also shows potential for scientific contributions.

Keywords

Quadrotor, Energy management system (EMS), Nonlinear flight control, Battery, State-of-Charge (SoC), State-of-Health (SoH), sensor fusion, adaptive filtering

Improvement of Al-Fly Ash Composites Characteristics by Equal Channel Angular Pressing

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Introduction

Modern researches in the area of technical materials are directed towards development of metal matrix composites, where aluminium and its alloys have wide application. Fly ash particles, which appear as a side-product of the coal combustion in thermal plants and present a serious ecological problem, can be incorporated into these composites as reinforcement. Fly ash is a low density material that consists of hollow spherical particles. Previous researches show that adding a sudden percentage of fly ash into composite improve its characteristics. In this research Equal Channel Angular Pressing (ECAP) process will be applied to composite material based on aluminium and fly ash that has been primarily casted. During the ECAP process previously prepared material is extruded through an L shaped mould cavity. Thereby significant shear forces and reduction of micro grains occur in the material deformation zone what causes improvement of material characteristics.

Aims

The aim of this study is to produce Al based composite with highest fraction of fly ash, suitable for ECAP processing. Physical, mechanical and tribological characteristics of the obtained composite will be improved as result of intensive plastic deformation during ECAP process. Testing results will quantify the influence of fly ash fraction and deformation degree to composite characteristics.

Methods

Characterisation of fly ash and initial alloy will be conducted in first phase. Determination of the main and side fly ash components will be executed by an energy dispersive X-ray fluorescence spectrometer (EDXRF method). With an inductively coupled plasma atomic emission spectroscopy (ICP-OES method) the content of the elements in traces will be determined. Mineralogical, morphological and thermal characterisation of the fly ash will also be conducted. Second phase foresees preparation of castings with 4, 8 and 12% of fly ash mass content. Samples with appropriate dimensions will be cut out from these castings and subjected to ECAP. Samples will be extruded four times with rotation of 90°. After each pass one sample will be separated to be used for characterisation. Porosity will be measured on all samples as well as quantitative and qualitative analysis of microstructure by the optical and scanning electron microscope (SEM). Micro and macro hardness by Vickers will be measured on all samples. Tribological properties of the samples will be determined by testing their resistance to solid particles (SiC) erosion.

Expected scientific contribution

Quantification of influence of significant plastic deformation degree at ECAP process and fraction of reinforce to physical, mechanical and tribological characteristics of Al based composite reinforced with fly ash particles. Development of Al based composite with addition of fly ash, primarily obtained by casting process, that has satisfactorily characteristics for production of light weight parts.

Acknowledgments

I would like to thank prof. Rede and prof. Maksimović for their expert advice and encouragement troughouth this project.

Keywords

Fly ash, ECAP, Metal Matrix Composites, Improvement, Characterisation

Hardmetals Coated with Plasma Activated Chemical Vapour Deposition (PACVD) Process

PhD candidate: Matija Sakoman
Mentor/s: Danko Ćorić
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Introduction

With daily growth of the world's industry scientists are faced with continues changes, visible on product's diversity, lifetime and quality demands. As a material for cutting processes hardmetals (WC-Co) stood out as an optimal material comparing the price and tool lifetime. In addition to good base materials, coating technology is the main way to improve a cutting tool performance. The area of application for hardmetal coated materials is expanding on a daily basis with the development and application of nano sized powders, as well as the advancements in coating technology. Plasma assisted chemical vapour deposition (PACVD), a process never before used for coating hardmetals with nano grain sizes, with its lower coating temperatures shows the potential of being an optimal process in avoiding microstructural defects in highly reactive nano hardmetals. From all of the above and after professional training in Fraunhofer IST, a leading institute in coating technology, an idea on developing a tool with superior properties was born.

Aims

The aim of this research is to design and manufacture a specially designed tool with superior tribological and mechanical properties. The usage of mentioned technologies is to significantly reduce the costs of manufacturing by reducing delays caused with tool change and tool damage.

Methods

Methods used in the research will be theoretical, experimental, mathematical and statistical. Theoretical phase is the research of the optimum grain sizes, grain growth inhibitors and sintering process which combined will allow a full density process. Experimental phase will include the powder characterization, consolidation, hardmetal sintering, and optimization of coating parameters for PACVD process. The statistical and mathematical analysis will show the influence of varied factors on a hardmetal product, as well as the influence of coating parameters on the final properties of a coated sample. A successfully sintered product will be coated by PACVD and the produced coatings will be tested in exploitation tests.

Expected scientific contribution

The research will significantly contribute to the adoption of new technologies in the field of powder metallurgy and coating processes which will enable the development of special materials with specifically designed properties. Activities within the pHd develop and introduce a combination of two technologies crucial for the final properties of hardmetal products. The coating procedure will enable a unified coating deposition on complex geometries. The research will give new insights on compatibility of the applied coating procedure and powder metallurgy technology. Results will significantly contribute to the development and application of hard coatings on hardmetals.

Keywords

hardmetals, sintering, coating, PACVD

Development of Early Equipment Life Cycle Maintenance Strategy Model

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Introduction

Developing Maintenance strategy for production equipment is essential work for maintenance experts. It is necessary to develop adequate, optimized Maintenance strategy that fulfils different requirements connected to availability of the equipment and also to reduce maintenance costs as much as possible. Since equipment purpose is to produce, any equipment non-available time period is generating loss of production and consequent costs. Maintenance strategy usually defines preventive maintenance activities only and corrective maintenance activities are not taken into consideration. To fulfil this gap, it is necessary to inspect potential failures, analyse failure consequences due to the costs and connect them to economical part of production – production costs. One of the methodologies useful to develop optimum maintenance strategy is RCM (Reliability Centred Maintenance). RCM is methodology based on Risk assessment through the application of FMECA (Failure mode, effects and criticality analysis) which is used to analyse potential failures. This method is base for developing maintenance strategy in early phase of equipment Life cycle. Different authors mostly use RCM to develop maintenance strategy during operational phase usually not taking production losses into consideration.

Aims

The main objective is to develop model which will define optimal Maintenance strategy in the early phase of equipment life cycle, earlier than equipment starts to fulfil its function. Using this Maintenance strategy, high level of production availability is to be achieved. Spare parts inventory is to minimize downtime. Requirements for knowledge and skills for maintainer and operator will be specified.

Methods

An adapted Failure mode, effects and criticality analysis (FMECA) is used to analyse potential failures and with downtime costs.

Expected scientific contribution

Model will, based on FMECA, calculate and incorporate maintenance costs and production losses due to the equipment unavailability. Maintenance strategy will be developed in the early phase of equipment life cycle.

Keywords

Maintenance, Maintenance Strategy, Reliability Cen-tered Maintenance (RCM), Failure Mode, Effects and Criticality Analysis" (FMECA)

Numerical Formulation of Fluid Structure Interaction Model Using Geometric Mechanics Approach

PhD candidate: Tomislav Sertić

Mentor/s: Zdravko Terze

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

Introduction

Standard methods to integrate motion equations are not efficient for systems with big rotations, geometric nonlinearitie, kinematic constraints etc. A classic approach to solve this kind of problems is by utilizing vector spaces which are linear. Novel approach for integration of motion equations is by using geometrical approach which means to integrate differential equations directly on manifolds. This research analyze coupling of dynamic fluid excitation with a structural multibody system based on geometrical approach utilizing Lie SO(3) group.

Aims

Goal of thesis is to develop and implement fluid – structure numerical model based on geometric approach using Lie SO(3) group to integrate equations directly on the manifold. Novel algorithm will provide possibility to include fluid excitation variables in Lie group and by that enable more efficient and stable solution finding of coupled problems. As part of the research it is expected that novel algorithm will be implemented and tested in the experimental setup.

Methods

The literature review will be made to research present approaches to solve similar problems, this will be useful to find out benchmark cases for newly developed algorithm. After literature review possibility to couple two phases, structural system and fluid will be investigated. Developed coupled model will be used to develop the numerical algorithm utilizing Lie group to integrate directly on manifolds with possibility to integrate both phases simultaneously. The last step of the research will be validation of developed algorithm based on comparison to other calculation methods and implementation to the experimental setup.

Expected scientific contribution

As part of this research it is expected that following contributions will be presented:

- Development of coupled fluid – structure multibody mathematical model on manifold using SO(3) Lie group
- Implementation and testing of developed algorithm inside experimental setup
- Better understanding of motion control procedures based on developed model

Acknowledgments

The author would like to thank prof. Zdravko Terze for advice and assistance. Also, I would like to extend my gratitude to my family and frends for support.

Keywords

Lie group, Geometric mechanics, SO(3) group, Fluid-structure interaction.

The Development of Methodology to Assess Capability of a System of Autonomous Agents

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Introduction

The use of systems of autonomous agents cover numerous applications in a number of activities. While operating, agents in such systems constantly measure certain parameters related to their states or to the state of their environment. A general accompanying characteristic of these measurements is that they are processed with statistical limitations in real time. If the ability of such a system is to be determined empirically, it is necessary to conduct multiple tests with time involved and energy consumed. Ability to assess capabilities of the system would enable the implementation of the system of autonomous agents on a larger number of qualitative various systems. Ability to assess capabilities of the system is defined as the ratio of required and implemented characteristic of system. The system is deemed competent if the ratio is large enough. Therefore, the lack of the methodology for assessing abilities severely suppresses the possibility of efficient and proper use of a system of autonomous agents. This research contributes to the development of a methodology for assessing the capabilities of the system of autonomous agents. Planned research includes the following phases: (i) collecting data on existing systems and defining the statistical distribution parameters, (ii) setting the model of a system of autonomous agents, (iii) validating the model and (iv) numerically simulating the action in parameterized environment. The purpose of the research is to understand the dynamics of system of autonomous agents. In other words, the objective is the development of a methodology that will enable unique determination of the system capabilities to perform a predefined action, based on known or estimated properties of the system's elements.

Aims

Preliminary research indicates wide application of agents in the structured environment. However, the literature has not been found determining assessing the capabilities of a system of autonomous agents. Their current application comes down to multiple repetitive simple tasks in familiar, idealized environments. Therefore the aim of this research is development of a methodology for assessing the capabilities of a system of autonomous agents.

Methods

In first part of research the plan is to collect data on the existing systems of autonomous agents and compute statistical distribution of the parameters. According to the statistical parameters further step is development of a theoretical framework of model of a system of autonomous agents. Validation of the model will be confirmed by analytical solutions. Basis for setup of simulation model of a system of autonomous agents will be methods of statistical mechanics and their probabilistic interpretation. Analytical and statistical tests will confirm the agreement of numerical results and analytical solutions. Comparison of solutions will enable the validation of system of autonomous agents in all fields in parameterized environment.

Expected scientific contribution

Expected scientific contribution is development of a methodology for assessing the capabilities of a system of autonomous agents.

Keywords

assessing the caassessing the capability of a system, measurement, numerical simulations, system of autonomous agentspability of a system, measurement, numerical simulations, system of autonomous agents

Development of a CNC System for Gear Hobbing Machine

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Introduction

Modern machining systems for spur and helical gear cutting are commonly based on the 5-axis machining centers and gear hobbing machines (GHM). Machining centers are generally more flexible, even though their application for gear cutting is somewhat limited compared to the GHM, due to the differences in their respective design stiffness. Modern CNC GHM compared to the conventional GHM have increased productivity and are well suited for mass gear production. However, such machines are also very costly and hence, not suitable for small series or single part production. In such production, focus is not based on high productivity but rather on the increased machine flexibility and low setup times.

Aims

Main goal behind this work is to provide a convenient solution for small series and single part gear production by developing a CNC system suitable for retrofitting a conventional GHM. By converting a conventional GHM into the CNC variant, a lower cost solution for such a production can be achieved, which is the motivation for this work. Additionally system is going to be upgraded with developed tool wear monitoring model.

Methods

This research is to be conducted in two phases. In order to realize the proposed research, a suitable testbed system has to be developed first. Such system has to be capable of synchronous servo control as well as the signal acquisition and processing in real time. Therefore, synchronization between the main spindle and feed drives is realized by applying encoder following drive control mode. Second part of research is based on experiment in which different cutting conditions are applied to different materials using gear hobs with different wear stages. During the cutting process multiple signals from different sensors such as force, current, vibration and acoustic emission will be continuously recorded. After the experimental part has been completed, signals are to be processed in order to extract a set of features sensitive to the changes of the tool wear. Such set of features will be fed to the different AI based classification algorithms in order to establish the most robust solution for the tool wear model.

Expected scientific contribution

The first phase, which has already been completed includes designing and assembling of the CNC control system. Basic support software has also been developed and tested in simulation mode as well as in the idle mode. As the system has not yet been fully installed on the testbed, the presented work can be considered to be in its early stage. However, results of idle drive motions tested on a number of different spur and helical gears show that the proposed system operates within specified requirements. The project is currently in the stage of hardware implementation on the testbed. Future research will be focused on the further development of the CNC support software and model for tool wear quantification. The model would be used for prevention of the tool breakage and possibly for the adaptive control of gear hobbing process. Both are of major importance for the development of new adaptive mechatronic systems for gear hobbing.

Acknowledgments

This research is financed and supported by TractorPro d.o.o. company specialized for small series and single part high accuracy gears production.

Keywords

Gear hobbing, Gears, Encoder following, CNC system, Tool wear monitoring

Aerodynamic Interference Analysis of Mixed Close Formation Flight

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Introduction

The benefit of formation flight is well known and has been studied for considerable amount of time. Improvement in aerodynamic performance has led researchers to investigate how aircraft in formation can obtain aerodynamic benefits, which lead to drag reduction and energy savings. One of the latest flight tests, conducted to investigate potential fuel savings, carried out by NASA, resulted in an average fuel flow reduction of 10%. Both numerical and experimental research emphasize the importance of finding the region of maximum decrease of induced drag and maintaining it. A mixed close formation consists of manned and unmanned vehicle flying in close proximity with streamwise separation up to few wingspans.

Aims

In order to investigate close formation flight, a detailed understanding of the coupling effects of aerodynamic interference of one vehicle upon another is required. The aim of this research is to develop a model of aerodynamic interference that could be incorporated in real-time or near real-time simulations. This paper investigates the effects of aerodynamic interaction between small Unmanned Aerial Vehicle (UAV) and small passenger aircraft, with considerably larger wingspan and weight, flying in close formation.

Methods

From a number of wake vortex modelling techniques that can be used for this purpose, extended lifting line theory offered acceptable computational time. The developed method was implemented, verified and successfully integrated within Matlab environment. Each aircraft is represented by its wing, which is replaced by series of equally spaced horseshoe vortices. The fuselage, friction drag, compressibility and the roll-up of the vortex sheet are note taken into account.

Expected scientific contribution

The presented theoretical development of the extended lifting line theory used for this analysis and numerical implementation of the model demonstrate the benefits and feasibility of such mixed close formation flight. The model can accommodate any type of wing geometry and, since the same technique was used to model both the leader and the follower, aircraft can exchange position during flight.

Keywords

Formation flight, aerodynamic interference, Unmanned Aerial Vehicle

Three Hour Storm Seakeeping CFD Simulation

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Introduction

Computational Fluid Dynamics (CFD) is getting more popular for the problems regarding ship seakeeping. The conventional methods based on potential flow theory are quick and accurate in most cases, but cannot asses extreme wave loading and added resistance due to waves. The three hour storm seakeeping simulation is a deterministic method were a specific realization of wave spectrum tthat corresponds to heavy conditions is imposed to asses ship response. CFD based on full form of the Navier-Stokes equations for incompressible two phase flow can capture nonlinear free surface effects in addition to viscous, turbulent and vorticity effects. The down side of CFD are the large required CPU resources, which usually prohibit simulating three hour of real time. The CFD code foam-extend with Naval Hydro pack allows rapid simulations enabled by advanced methods for wave propagation, free surface boundary condition treatment and rigid body motion-fluid flow coupling. In this work an example full scale three hour storm seakeeping simulation is shown for DTC (Duisburg Test Case) ship.

Aims

The aims of this work is to investigate the possibility and advantages of the CFD method for calculating extreme wave loads as a complement to the potential flow based methods.

Methods

A Finite Vlume (FV) based CFD method is used in the open source software foam-extend, with arbitrary polyhedral cell support. k-ω SST model is used for turbulence modelling, while Level Set (LS) method with implicit redistancing is used for interface capturing. Ghost Fluid Method (GFM) is used to implicitly account for the pressure gradient and density jump across the interface, removing spurious air velocities problems. SWENSE (Spectral Wave Explicit Navier-Stokes Equations) method is used for solution decomposition, allowing explicit propagation of incident wave field.

Expected scientific contribution

The work is suppose to demonstrate to which degree are the modern CFD methods applicable to long seakeeping simulations needed in industry. The application of CFD for these kind of calculations would increase the accuracy of extreme seakeeping predictions.

Keywords

Seakeeping, Three Hour Storm, CFD, foam-extend

Harmonic Balance Method for Turbomachinery Applications

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Introduction

Harmonic Balance method for non--linear, temporally--periodic incompressible flows is presented in this work. Assumption of a time periodic flow allows us to formulate 2n+1 coupled steady state problems using Fourier series expansion. By solving 2n+1 steady state problems, we obtain a flow field with transient effects. Fourier series expansion is the core of the Harmonic Balance method, therefore the accuracy of the method depends on the number of specified harmonics, n. Moreover, the accuracy of the method also depends on the periodic nature of the problem. The Harmonic Balance method will be presented on turbomachinery test cases and compared to conventional steady-state and transient solvers.

Aims

The method was previously successfully validated and verified on pitching airfoil and pitching wing test cases. Its applications will now be further extended to include moving mesh and multiple frequencies, and presented on turbomachinery cases. Harmonic Balance results will first be compared against conventional steady state solver using Multiple Reference Frame (MRF) approach. Head, efficiency and power will be compared, as well as the flow field details at specific locations of interest. Additionally, Harmonic Balance method will be compared against conventional transient solver, discussing the accuracy and simulation speed—up.

Methods

The accuracy and simulation speed-up of the Harmonic Balance method will be presented for the well established 2D ERCOFTAC centrifugal pump geometry. Steady-state solution with MRF and transient solution will be compared against several Harmonic Balance solutions with different number of harmonics used. Higher number of harmonics used provide more accurate solution but yield longer simulation time. The implementation is carried out in a second--order accurate, polyhedral Finite Volume framework developed within foam--extend, a community driven fork of the OpenFOAM toolkit.

Expected scientific contribution

The Harmonic Balance method should provide an efficient compromise between accuracy and efficiency as it is capable of capturing transient flow features, while still providing a significant CPU time decrease. Steady state methods lack transient effects, but provide reasonable CPU time savings. On the other hand, transient simulations usually require unacceptably large computational resources in order to achieve periodic steady—state solution.

Keywords

Harmonic Balance, periodic flow, turbomachinery, CFD, Fourier series

Hemocompatibility of Bladeless Centrifugal Heart Pump

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Introduction

In recent years, ventricular assist devices (VAD) and total artificial hearts (TAH) had become unrivalled tools for replacing a failed heart. Heart pumps are typically used to bridge the time to heart transplantation, or to permanently replace the heart in case heart transplantation is impossible.Through previous development and implementation, it was observed that pumps with continuous-flow output cause less blood damage and have superior properties than volumetric pumps with pulsating output. Further research aims to improve pump design in order to achieve greater hemocompatibility.

Aims

Aim of the research is to develop bladeless centrifugal pump design for total artificial heart by adaptation of principles of Tesla pump. It is expected that new bladeless centrifugal pump will cause less shear stress, as the flow is created due to adhesive and cohesive forces, without impact of blood cells on rigid blade surfaces. This will enable greater hemocompatibility.Study will research the physics of flow within the bladeless centrifugal pump, and influence of design parameters on the blood flow and pump hemocompatibility. Design parameters are pump head and flow, internal and external disc diameter, amount and distance of discs, angular velocity and housing geometry. Base criteria in heart pump development are pump head and flow. For the base criteria it is necessary to develop blood pump of acceptable hemocompatibility. Indicators of hemocompatibility are: leukocyte and erythrocyte damage (hemolysis) as well as thrombosis. Additional important factors are that heart pump can fit a body of small stature and has high performance, high durability, anatomical fitting, better hemocompatibility and physiological control.

Methods

Bladeless centrifugal heart pump design is based on turbomachinery theories and applying CFD methods. Hydrodynamic flow parameters will be calculated using k – ε turbulence model. Values of shear stress and stagnation zones, as well as blood recirculation zones will be calculated in order to develop blood pump of greater hemocompatibility. For a series of numerical simulations with defined pump head and flow, maximal hemocompatibility will be found by varying outer disc diameter, amount and distance of discs, angular speed and housing geometry.Experimental measurements will be performed using mock circulatory system with water and solution of water and glycerol (blood substitute) for the calculated maximum hemocompatibility pump design. Results of numerical simulation will be verified by comparison of measured and calculated pump head and flow.

Expected scientific contribution

Research and development of the bladeless centrifugal blood pump will be done numerically and experimentally. Impact of design parameters on hemocompatibility will be defined in order to reduce overall blood damage caused by heart pump. Up to date, volumetric blood pumps with diaphragm and pulsating output were developed, as well as bladed centrifugal blood pumps with continuous output. In the previously developed heart pumps mechanical energy was transferred by shape (blades or diaphragm), therefore using bladeless pump as heart pump is complete novelty.

Keywords

Centrifugal heart pump, bladeless, Computational Fluid Dynamics, hemocompatibility

FINAL PHD TOPICS

Decomposition CFD Model for Marine Hydrodynamics

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Introduction

Due to immense increase in computational resources during the past two decades, the Computational Fluid Dynamics (CFD) is becoming an important and inevitable tool for marine hydrodynamics. A large portion of marine hydrodynamic flows comes from wave structure interaction where the solution is often sought in time domain. In potential flow models, the wave systems are often described with analytical expressions (Green functions), whereas in CFD models relying on Navier – Stokes equations, the wave systems are presented purely numerically, hindering wave propagation in a CFD domain. A decomposition model is proposed in this work where the fully non – linear, two – phase and turbulent perturbation around an explicit and less accurate potential flow model is solved.

Methods

The numerical model is based on existing solution decomposition framework via Spectral Wave Explicit Navier – Stokes Equations, where the perturbation around a potential flow solution is solved. Explicit treatment of incident wave allows efficient introduction of wave systems in the CFD domain. The implicit relaxation zones are used to prevent undesired wave reflection off far – field boundaries by forcing the perturbation components to vanish. The implicitly redistanced Level Set method is used for interface capturing, where the signed distance field is directly used for second – order accurate discretisation of pressure and density jump conditions at the free surface via the Ghost Fluid Method. Hence, an infinitesimally sharp jump (discontinuity) of dynamic pressure and density is correctly achieved in the present numerical framework. The numerical framework is implemented in foam – extend – 3.2, a community driven fork of the OpenFOAM open source software.

Preliminary results

The method has been recently thoroughly validated regarding seakeeeping of a Kriso Container Ship model in head and oblique waves at design Froude number and high Brard numbers, comparing the CFD results with experimental measurements. Furthermore, the numerical framework has been verified by performing various sensitivity studies and assessing numerical uncertainties regarding time step size, grid resolution and hydro – mechanical (fluid flow – 6 Degrees of Freedom) coupling.

Discussion

The validation and verification proved that the present numerical model is highly suitable for seakeeping simulations, providing accurate results. An optimized performance test revealed the possibility of hull shape optimisation with respect to added resistance in waves since the required CPU time is extremely low (one minute per encounter period on a 56 cores cluster).

Keywords

Solution and Domain Decomposition, Implicitly Redistanced Level Set, Ghost Fluid Method, OpenFOAM, Seakeeping

Identification of the Low-Temperature Heat Release in the Experimental SI Engine

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Introduction

To achieve better brake specific fuel consumption (BSFC) in SI engines, compression ratio is raised, but it is limited with engine knock. Different strategies are used to avoid engine knock phenomena, and one of them is the application of the exhaust gas recirculation system (EGR). Understanding of the knock phenomena by identification of combustion parameters like Rate of Heat Release (ROHR) and characterization of the EGR through experiments represents the motivation for this research. The aim of this research was data acquisition on the experimental setup, required for research of combustion parameters such as Low-Temperature Heat Release (LTHR) on the engine knock occurrence. On the basis of experimental results conclusions that will lead to suggestions for upgrade of engine control management are expected.

Methods

The main method is based on the research on the experimental engine setup. For experimental research single-cylinder SI CI Engine coupled with AC Dyno is used. Furthermore, the testbed is upgraded with in-cylinder pressure and engine positioning measurement (AVL Indismart), in-house developed software for regulation of the IC Engine (via National Instruments equipment) and AC Dyno control (via Siemens equipment). Data acquired on the experimental setup is further processed to obtain results of Low-Temperature Heat Release.

Preliminary results

During some preliminary tests performed with an experimental single cylinder engine, strong tendency to knock occurrence was observed, but was preceded by the appearance of low-temperature heat release in the bulk charge even before the spark discharge. The tests were performed on a diesel Engine Hatz 1D81Z that is converted to SI operation with compression ratio 12.

Discussion

It is expected that that better understanding of the knock phenomena by identification of combustion parameters through experiments will result in scientific contribution of this research. Research of the LTHR influence on the IC Engine combustion process gives important development solutions through numerical simulations. These solutions are to be validated through experimental testing on the engine testbed.

Acknowledgments

Due to the requirements for reduction of CO2 emission (fuel consumption) and meeting the limit values for pollutant emissions, the objective in IC engine is to keep the engine operating point at high load. On the other hand, because of the high load and high charging pressure the tendency of engine to knock occurrence increases.

Keywords

Experimental setup, Combustion, SI IC Engine, En-gine knock, LTHR

Experimental Testing of the HCCI Engine

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Introduction

Legal limits for permissible values of pollutants from internal combustion engines are constantly reduced. In order to reduce air pollution and to achieve these limits, new combustion processes in engine cylinder are constantly developing. One of these processes is HCCI (Homogeneous Charge Combustion Ignition). HCCI engine has the advantage of lower emissions of nitrogen oxides (NO_X) and particulate matter (PM), and at the same time high efficiency. An additional benefit of HCCI engine is the ability to work with a variety of fuels, which is particularly interesting when using energy from renewable sources such as biofuels in liquid or gaseous state. In addition to these advantages, the main disadvantage is difficulty to control the combustion process which is the main reason for a lack of implementation of the HCCI engine in commercial purposes.

Methods

In the Laboratory for IC Engines and Motor Vehicles of the FMENA, an experimental setup for IC engine testing is developed. Experimental engine is made by modifying single cylinder diesel engine. Experimental engine after minor modifications can operate in spark ignition (SI), and in HCCI mode. The experimental setup allows measurement and acquisition of various values that can be divided into two groups. The first group of data indicates combustion process quality in the engine cylinder, e.g. indicated mean effective pressure (IMEP), the rate of heat release (ROHR), etc. while the second group of data determines basic characteristics of the IC engine such as torque, power, specific fuel consumption and NO_X emissions. In this study, HCCI engine is propelled by gasoline fuel EUROSUPER BS 95 (RON 95).

Preliminary results

By reviewing the literature, it can be concluded that the HCCI engine management is not a simple task. To analyse the combustion processes in the engine cylinder, experimental testing of the HCCI engine was required. Main goal was to determine the influence of air to fuel mixture and intake air temperature on the engine indicated mean effective pressure, the rate of heat release, ringing intensity, NO_X emissions, torque and power of the engine.

Discussion

Due to the positive characteristics of HCCI engine in terms of reducing emissions of pollutants, further development of this engine can be considered very useful. If the HCCI engine is propelled with fuels obtained from renewable energy source the positive impact to the environment is even greater. It is expected to determine the working parameters of the HCCI engine and ability for the engine to work in wide range of loads, which means a larger range of engine applications.

Acknowledgments

This research is partly financed by the project: "Experimentally Supported Development of Advanced Internal Combustion Engine Models" financed by Croatian Science Foundation in cooperation with AVL AST Ltd.

Keywords

HCCI engine, experimental engine testing

The Effect of Various Engine Operating Parameters on Dual Fuel Combustion Process

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Introduction

This study presents the effect of injection pressure, pilot fuel mass (diesel fuel) and direct injector nozzle number on dual fuel combustion process. A part of the presented results (effect of injection pressure and pilot fuel mass) were obtained experimentally on a 2 liter VW Jetta engine that was modified to work in a dual fuel mode. As it is difficult to study various combustion aspects experimentally, the effect of direct injector nozzle number was studied numerically with a newly developed 0-D dual fuel combustion model.

Methods

In order to achieve the defined objectives of this work, it was necessary to carry out several activities. Hence, this work can be divided into two basic parts. The first part includes the modification of the existing 2 liter Diesel engine to operate in a dual fuel mode. The second part refers development of 0-D dual fuel combustion model within the AVL cycle-simulation software.

Preliminary results

The experimentally and numerically obtained results clearly show that the assessed engine operating parameters have a profound impact on dual fuel combustion process. Injection pressure not only changes the start of combustion, but it also has an effect on the combustion rate. The change in pilot fuel mass also has an impact on the start of combustion and combustion rate. Numerically obtained results indicate that the change in nozzle number changes the number of flames that propagate through the combustion chamber, thus changing the overall flame surface and rate of heat release.

Discussion

As indicated in the previous section ("Preliminary Results"), all assessed operating parameters profoundly affect the dual fuel combustion process. Some of them affected the process in and expected way (pilot fuel mass). In this case as the pilot fuel mass increased, start of combustion was advanced and combustion rate actually increased. The increase in the injection pressure on the other hand caused the retard in the start of combustion moment and decrease in the combustion rate due to better mixing between the pilot fuel and surrounding fresh charge. Nozzle number change showed the trend that was expected, however it was interesting to notice that as the number of nozzles increases, the effect of nozzle number increase on rate of heat release decreases. Overall this study also showed that not all important engine parameters can be studied experimentally, and that there is a clear demand for the development of physically based, fast combustion models.

Acknowledgments

This work was done within the FMENA project "Experimental Research, Optimization and Characterization of Piston Engine Operation with Dual-Fuel Combustion", funded by the Croatian Science Foundation.

Keywords

Internal combustion engine, dual fuel combustion; cycle-simulation, experiment

Thermodynamic Efficiency Improvement of Combined Power Plant's Bottom Cycle by Using Organic Working Fluids

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Introduction

A new method of determining an optimal heat recovery steam generator (HRSG) heat exchangers layout and its operating parameters using water and ORC as working fluids is presented in this work. A robust mathematical model is developed where an arbitrary steam pressure levels and steam reheater levels can be set up.

Methods

Heat exchangers are designed in form of a heat exchanger network. In direction of a flue gas stream there are an arbitrary series of heat exchangers that represent different steam pressure levels or steam reheaters levels. This set up enables paralel arrangement of any two or more heat exchangers belonging to different steam pressure levels or reheating levels. The size of individual heat exchanger is determined by specifying its enthalpy increment. Using genetic algorithm as an optimization technique, where optimization variable are heat exchanger surfaces, steam pressures and steam flows, it is possible to obtain both an optimal HRSG heat exchangers layout as well as the optimal operating parameters. The specificity of the method is the fact that it covers all the possible heat exchanger layouts, both in serial and parallel heat exchanger position between different steam pressure levels or steam reheater levels. In this work the maximum thermodynamic efficiency of the steam turbine cycle was set as the objective function.

Preliminary results

The calculation results for double steam pressure level HRSG's, with and without reheating, are presented. The results show that the optimal working fluids are acetone, R11 and R123 regardless flue gas inlet temperature. Also, thermodynamic efficiency rises as flue gas input temperature rises. Biggest difference in thermodynamic efficiency between ORC and water as working fluid in second pressure level is at lower flue gas inlet temperatures.

Discussion

Results have shown that by using HRSG with possibility of generating serial and parallel heat exchanger network layout and by using organic fluids in lower pressure levels of combined cycle power plant greater thermodynamic efficiency can be achieved.

Keywords

Bottom cycle, Rankine, ORC, HRSG

Development of Numerical Models Within the Liquid Film and Lagrangian Spray Framework

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Introduction

Different environmental regulations impose ever stringent limitations on flue gas emissions from industry and transport as a part of the air pollution and global warming problem solution and with it connected climate changes. Fossil fuel combustion emissions are influenced by the quality of mixing process between combustion air and fuel and flue gas aftertreatment system efficiency. From the above it is clear that the industry and transport are facing major challenges which can be only met by the development of new and more efficient systems using advanced tools for product development, one of which is computational fluid dynamics. This research is going to address three different areas all of which could be found within different industrial applications – liquid film rupturing, multicomponent liquid film evaporation and urea deposit formation and its chemical kinetics.

Methods

This work will numerically describe liquid wall film phenomena through further upgrade of the existing mathematical framework based on the conservation laws of physical quantities. Within the commercial software package for computational fluid dynamics based on the method of control volume which will be used for research, spray droplets are described using the Lagrangian formulation, whilst the gaseous phase and wall film are solved by the Eulerian formulation. Developed mathematical models are going to be implemented by employing FORTRAN-based user functions that are connected to the main solver. It is expected that this research will define models for liquid wall film rupturing, multicomponent evaporation and chemical kinetics of urea deposits. After coding and implementation of all user functions, validation simulations are defined. They include generation of computational mesh, setting of initial and boundary conditions and selection of the appropriate differencing schemes and other relevant parameters of the solver.

Preliminary results

Verification of the film rupturing criterion was obtained through qualitative check of cell position where separation occurred and through manual calculation of separation criterion for activated cells. Urea thermal decomposition model was implemented in commercial CFD code and tested on the experiment where biuret was heated up in a test tube from room temperature with a heat rate of 2 K/minute. The validation of the multicomponent evaporation model was performed on two experimental set-ups, namely evaporation of two component liquid mixture in quiescent environment and strongly turbulent air flow conditions over the multicomponent film surface in the narrow gap (3.9 mm). Implemented model qualitatively captures behavior of liquid components in quiescent case but the evaporation rate is underestimated, whilst the evaporation in narrow gap case is satisfactorily described.

Discussion

The developed numerical framework in the area of liquid wall films has been proved to be sufficiently accurate on the series of selected validation cases and can be used as a tool in the modern development process of various industrial devices. Recommendation for future work should entail employing more detailed description of liquid wall film temperature and composition and its comparison versus currently developed model in terms of result's accuracy and computational demands.

Acknowledgments

The candidate wishes to thank AVL List GmbH, Graz, Austria for the financing of the project.

Keywords

Computational fluid dynamics, wall film rupturing, selective catalytic reduction, urea thermal decompo-sition, multicomponent evaporation

Advances in Pressure-Velocity Coupled Solver

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Introduction

Computational fluid dynamics (CFD) tools are regularly used for complex, coupled and non-linear heat and mass transfer problems. With the development of modern computers and accessibility of High-Performance Computing (HPC) clusters with substantial memory resources, early compromises in the concept of simulation tools can be revisited. The system of equations is usually dominated by inter-equation coupling terms. Most algorithms use conventional segregated approach and solve the equations sequentially. New solution techniques rely on linearisation of inter-equation coupling and solution in an implicit coupled manner. The benefits of the coupled approach are significant reduction in time-to-solution and numerical stability of the algorithm, but at a cost of increased memory usage.

Methods

PISO and SIMPLE are still most widely used algorithms for solving Navier-Stokes equations. These algorithms solve the inter-equation coupling in a segregated manner, which means solving the momentum equation with wrong values of pressure and solving the continuity (pressure) equation with non-conservative values of velocity. The decoupling of these linearly dependent variables causes slow convergence. The new pressure-velocity coupled algorithm based on the finite volume method solves the equations simultaneously: the equations are written in a single matrix. The unknown for each cell becomes a vector whose components are the three directions of velocity and pressure. The matrix of the coupled system is most efficiently solved by employing algebraic multigrid and Krylov subspace methods.

Preliminary results

The coupled solver was validated for several test cases. The results of the calculation of flow around racing car aerodynamics coincide with the experimental data well. The performance of the solver was compared for calculations of flow through centrifugal pumps, engine cooling and turbine blade passages. The most notable advantage compared to the segregated solver is no need for underrelaxation of the pressure and very high underrelaxation factors for velocity (>0.9). The solver is more stable and converges in less iterations. However, the spectral analysis of the matrix has shown that the matrix is ill-conditioned and it requires development of appropriate preconditioners and linear solvers.

Discussion

The coupled solver performs better than the segregated due to the characteristics of the Navier-Stokes equations. The connection between velocity and pressure is linear, thus, it's possible to write the equations into a single matrix. The non-linear connection between velocity components must be linearised and thus the velocity needs to be underrelaxed. The matrix of the coupled system is ill-conditioned and is not diagonally dominant which causes the slow convergence of the multigrid methods which use conventional iterative solvers as smoothers. The Krylov subspace methods which are generalized for indefinite matrices, such as the biconjugate gradient stabilised method, converge faster compared to the multigrid methods. Future work includes development of new linear solvers and preconditioners for the coupled system.

Keywords

Pressure-velocity coupling, CFD, OpenFOAM, linear solver

Potential Role of District Heating Systems in Contemporary Energy System

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Introduction

The contemporary energy system is faced with new challenges on the energy market. Both the rising share of renewable-based electricity (characterised by intermittent production) and increasing energy efficiency in buildings induce a reconsideration of the traditional role of conventional power plants coupled with district heating systems along with its impact on the energy system. Moreover, the price of electricity determined by the merit-order system additionally decreases the load factor of such plants, making them less competitive or even inflicting financial loss in operation.

Methods

Research presented in this paper focuses on a novel approach towards conventional CHP plants coupled with district heating systems. It involves an analysis of dynamical performances of the district heating system – capability of energy accumulation and thermal inertia – in order to assess its potential to become part of ancillary services. A comprehensive analysis of dynamic behaviour of the district heating system has been performed by means of a mathematical model developed as a part of this research. The model is implemented on a theoretical case consisting of a simplified district heating system with three final users and the pipeline network of 9000 m in length.

Preliminary results

It is concluded that the district heating system, i.e. network of pipelines can be considered a dynamical thermal energy storage in which excess energy can be stored during operation of the power plant (CHP). The simulation has shown that the storage capacity of the network depends on the thermal load in the network and in such circumstances specific thermal capacity of the network amounts to 10,1 Wh/(Km). Moreover, the thermal capacity of the network increases as the pipeline length declines which is characteristic of densely populated areas. The capability of energy accumulation is explored for different parameters, such as: external temperature, distance of the network, supply water temperature etc.

Discussion

The operation strategy of the district heating system has a significant impact on the way these systems coupled with CHP plants can be utilized in contemporary energy system. The thermal energy storages enable more flexible operation strategy of CHP plants, i.e. with integrated thermal storages it is possible to gain additional profit on the energy market. It is shown that the district heating system can be deployed as the dynamical thermal storage. The amount of heat, i.e. energy that can be stored within the pipeline network depends on several factors. The most important ones are the heat demand of the final users, the length and diameter of the pipeline. By decreasing the heat demand the decrease in the accumulated heat is noticed as well. Moreover, it can be stated that the farther away from the source of disturbance the final users are situated, the greater amount of accumulated heat can be used to compensate for heat reduction from CHP plant.

Keywords

District heating, CHP, dynamical thermal storage, mathematical modelling, operation strategies

Numerical Simulation of Lubricated Wire Rolling and Drawing

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Introduction

Friction and lubrication are important factors in metal forming processes. Unoptimised frictional parameters can cause lower productivity of manufacturing machinery and deteriorate surface quality of the final product. Optimised frictional parameters are, in most cases, achieved by controlled lubrication of contact between product and forming machine. Lubricant and contact surfaces experience high pressures with temperature and velocity variations. Due to these effects both material and lubricant properties are changing, which can have significant influence on the shape and quality of the final product. Numerical modelling of metal forming processes reduces time and cost of the physical experiments required when a new type of metal product is introduced into production. This thesis deals with numerical modelling of lubricated contact between two surfaces during wire rolling and drawing processes using Finite Volume Method and OpenFOAM software.

Methods

Lubricated contact between surfaces in relative motion can be divided into three regimes: hydrodynamic, mixed and boundary lubrication regime. In mixed and boundary lubrication regime contact pressure is shared between asperities in contact and lubricant. Due to different lubrication regimes both solid-solid and solid-fluid contact models are formulated, implemented and coupled in order to give a good representation of all lubrication regimes. For solid-solid contact Greenwood-Williamson model is implemented. GW model is based on the Hertzian theory where asperities are considered hemispheres with elastic deformation. Average Reynolds equation is used to calculate hydrodynamic lubricant pressure and shear stress. Hydrodynamic and asperity contact pressures (and shear stresses) are coupled together over contact area ratio into total pressures (and total shear stresses) on the contact surface. Average Reynolds equation is discretised using Finite Area Method. Contact model is implemented as a boundary condition in numerical package for metal forming, developed in collaboration between Bekaert, UCD Dublin and UNIZAG FSB, based on OpenFOAM software.

Preliminary results

Preliminary results show significant dependence of hydrodynamic pressure on lubricant viscosity and surface velocities during sheet rolling simulations. With increasing lubricant viscosity from 0.5 to 2 Pas, maximum hydrodynamic pressure increases by 400%. With increasing roller speed from 60 to 120 RPM, hydrodynamic pressure increases by 310%. Maximum asperity contact pressure also increases with roller speed.

Discussion

Since hydrodynamic pressure shows significant dependence on lubricant viscosity, implementation of lubricant property models is required for density, viscosity and heat conduction. Contact heat transfer model will be implemented. Solid-solid contact model will be expanded with elasto-plastic asperity deformation algorithm. Lubricant cavitation effects need to be investigated. Implemented models need detailed validation and verification.

Keywords

Lubricated Contact, Finite Area Method, Reynolds Lubrication Equation, Metal Rolling, OpenFOAM

Dynamic Performance Enhancement of High Temperature Latent Heat Storage

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Introduction

100% renewable energy systems cannot be realized without large energy storages. Energy storages are divided on electric and heat storages while heat storages can further be divided on sensible heat and latent heat storages. Focus of this paper is on high-temperature latent storages, also known as Phase Change Materials (PCM) storages. High-temperature PCM is well known technology, which has not seen wider use due to the some inherent weaknesses (corrosion, low thermal conductivity, price, etc.). Although relatively high number of different high-temperature PCM materials is recommended in various literature, mostly including different inorganic salts and eutectic salts, very few were actually used and can provide some experimental or real application data. In this paper new mathematical model of heat transfer and phase change inside of high-temperature PCM is developed and verified with experimental results. Obtained results are than used for the systematic storage geometry improvement with a goal of improving overall performances of heat exchange. While most of the focus will be on one specific PCM ($NaNO_3$) other PCMs will also be considered.

Methods

The base of this research is comprehensive mathematical model of PCM behavior. Both 2D and 3D models will be used. Because high-temperature PCM modeling is relatively new field of research there is significant lack of reliable input parameters (material properties such as heat conductivity, viscosity etc). Furthermore, amount of experimental data that can be used for model validation is scarce. Therefore, a number of experiments will be made to confirm material properties and validate model. Since simulation of charging and discharging processes require high processor resources, especially in case of 3D models it is necessary to reduce the number of simulation runs. Therefore statistical methods (such as Taguchi methods, RSM and others) will be used for design improvement.

Preliminary results

Two different mathematical models of PCM melting and solidification were developed. First one is without convection modeling and second one with convection. So far models were validated using experimental data in a form of the one point temperature available in literature. Models comparison has shown that convection model is better, especially during melting when more of 60% material is melted. During solidification process, differences between models are very small, but the results from the model with convection still have better correlation with experimental ones. However processor time necessary for the second model is two orders of magnitude higher.

Discussion

As it is shown in literature, the dominant heat transfer mechanism during the melting process is convection, while the solidification is dominated by conduction. Since PCM storage bottleneck is the low heat conductivity in solid state, some models for simplicity disregard convection. Nevertheless preliminary results show that differences can be significant and of crucial importance for the complex geometry heat exchangers design. Differences in results are even more distinctive in cases where solidification occurs after partial melting.

Acknowledgments

Experimental equipment used in this research was partially funded by Support for scientific research program by University of Zagreb.

Keywords

High-temperature PCM, storage modeling, performance enhancement

Experimental and Theoretical Research of Geothermal Heat Pump

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Introduction

Low enthalpy geothermal energy is a renewable energy source that cannot be utilized directly for cooling or heating due to its inappropriate temperature level; therefore heat pump systems coupled to the ground heat exchangers are used. The long-term performance of system is dependent on the thermal balance between the heat extraction and injection into the ground, while the rate of heat transfer is limited by ground and borehole thermal properties. Heterogeneous underground, with vertically distributed properties, cause varying heat exchange rate along the borehole heat exchanger during operation and influence the temperature distribution in the underground. Aim of this research is development of model of the heat pump coupled to the borehole heat exchanger in stratified ground with different thermal properties. Hence, characterization of influence of vertical variability of ground thermal properties on efficiency of geothermal heat pump system and resulting temperature field around borehole is possible.

Methods

Research comprises of experimental investigation and simulation of system for analysis of influential parameters. Temperature changes inside and outside of the borehole are monitored by application of distributed temperature measurements. Borehole heat exchanger equipped with fiber optic sensors is installed and coupled to the propane heat pump used for conditioning of the two computer classrooms. Relevant parameters are monitored, including temperatures and heat flows of hydraulic system, propane cycle pressure and temperature together with electricity consumption of all components. Mentioned set up enables calculation of real seasonal performance factor (SPF) and development of the model of heat pump and borehole heat exchanger in stratified underground.

Preliminary results

Determination of composition and thermal properties of the underground are made. Distribution of thermal conductivity and borehole resistance is obtained by distributed thermal response test (TRT), as is the undisturbed ground temperature and geothermal gradient on location. Initial measurements are used for optimization of heat pump system performance. Daily monitoring results in cooling mode show the influence of underground disturbed temperature profile on the heat pump efficiency.

Discussion

In literature, vertical variability of ground thermal properties have been investigated in terms of its influence on procedure for determination of effective thermal properties. Based on the results obtained by distributed TRT, modelling of stratified underground as heat sink and source is possible. When coupled to the heat pump model, based on the experimental monitoring of the system in use, influence of the vertical variability of ground thermal properties on resulting efficiency of geothermal heat pump system can be observed. Model will be used for simulations to analyze effect of different parameters of borehole heat exchanger design on the resulting temperature field inside and outside of the borehole and to develop strategies for the efficient system operation when unbalanced use of geothermal energy is dominated by the cooling needs of conditioned area.

Acknowledgments

Research is conducted in the scope of the project "Research and the Promotion of the Use of Shallow Geothermal Potential in Croatia" (Grant no. IPA2007/HR/16IPO/001-040506).

Keywords

Geothermal heat pump, ground thermal properties, borehole heat exchanger, simulation model

Impact of District Heating on Future Energy Systems – Heat Mapping and Energy Planning on a Case Study of Velika Gorica

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Introduction

Highly efficient cogeneration and district heating and cooling systems have a significant potential for primary energy savings and CO2 emission reduction which are still highly underutilized in most European countries. They also play a key role in future energy systems planning due to the increase in the utilization of waste and renewable heat that they can enable. The flexibility they can provide, especially when heat storage systems and power to heat technologies are used, can also have a very positive impact on the increase of utilized intermittent renewable energy sources, for example wind and solar in the power sector. Such an integration of the heating, cooling and power sectors can, if designed correctly, increase the overall utilization of renewables, reduce the energy costs and CO2 emissions and help increase the security of energy supply in the overall energy system.

Methods

In order to ensure optimal levels of district heating penetration into an energy system a comprehensive analysis is necessary to determine the actual heating demands as well as the potential energy supply from waste and renewable sources. The goal of this work is to utilize a combination of hourly heat demand modelling, georeferenced heat demand and supply mapping and energy planning to determine economically feasible limits of district heating utilization from the perspective of an energy system as a whole. The heat demand mapping has been performed using ArcGIS and the energy planning using EnergyPLAN on a case study for the city of Velika Gorica.

Preliminary results

The preliminary results preformed in the framework of this research have shown that the integration of district heating in a combination with power to heat technologies has the potential to increase wind and PV shares in the power sector of the observed energy system as well as the potential to reduce primary energy consumption, and with that increase the security of supply, as well as reduce greenhouse gas emissions. Preliminary heating and cooling demand maps have also been created and validated.

Discussion

It is crucial to determine the overall economic benefit of a high level of utilization of district heating from an overall system perspective when power to heat technologies are utilized since they present a connection of the power and the heating and cooling sectors. The demonstrated heating and cooling demand maps as well as scenario analyses can greatly help in these evaluations.

Acknowledgments

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Keywords

District heating, Heat demand mapping, Heat demand modelling, Renewable energy sources, Energy planning

Advanced Planning of Energy Self-Sufficient Wider Urban Areas Using Smart Energy System Approach

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Introduction

The Republic of Croatia encourages penetration of renewable energy sources (RES) into the power system, in order to reduce pollution, encourage the exploitation of its own natural resources and to achieve the independence of the energy sector. In accordance with the above, this research will be carried out in the field of energy planning for the selected Dubrovnik region. The plan is to provide energy plan models by the year 2050 which will be based on the 10 minute data input, using advanced planning and smart energy system approach. The aim is to prove that the energy system, with 100% share of RES in energy production, could be self-sufficient, including the replacement of all conventional vehicles with electric vehicles (EV), as well as providing additional storage facilities by transforming power to heat and to cold and replacement of two-tariff model in electricity prices with the electricity market.

Methods

Borders of the selected energy system of a wider urban area will be defined with the general definition that can be applied to other regions. Defined borders will determine input data needed to do the calculations for energy plan model of the selected region. Calculations will be done in EnergyPLAN model, which is a deterministic input/output model for Energy Systems Analysis and runs on an hourly basis, and compared with the new algorithm based on 10 minute data input and modelled according to the EnergyPLAN.

Preliminary results

The Dubrovnik region was selected for its great potential of RES, including solar and wind potential. Their intermitted generation patterns cause insecurity in the power system supply since they depend on weather conditions. Linear correlation and regression of the solar radiation, wind speed, air temperature and electricity demand of the selected region are done for the consecutive three year period in order to compare the results of the mean monthly and 10 minute time step data. Calculations based on the 10 minute time step showed weaker correlation and regression results than the ones gained by mean monthly data. Linear correlation results of all variables except wind speed showed that their distributions in 10 minute time step slightly vary between consecutive three years period and they can be forecasted using linear regression line.

Discussion

Development of a new model will result in reducing the need for the additional flexibility in the system and providing more opportunities for stabile integration of 100% share of RES in the energy system. Integrated electricity market model, based on the 10 minute time step of trade, will ensure the stability of the system and regulation of energy flows, enabling market valuation of flexibility sources in the system. Cost-effective participation in the system for all its participants can be achieved using information and communication technologies.

Acknowledgments

I would like to thank Croatian Meteorological and Hydrological Service and Elektrojug Dubrovnik – HEP ODS d.o.o. for providing data for this work.

Keywords

Energy planning, electric vehicles, renewable energy sources

Optimal Shift Control for an Automatic Transmission with a Large Number of Gears Including Potential of Extra Clutch Control

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Introduction

New generation of torque converter automatic transmissions (AT) includes a large number of gears for improved fuel economy, reduced emissions, and enhanced driving comfort. Due to the significant number of inactive clutches during a shift, there may be a potential for an unconventional control approach using extra clutch(es). Normally-open (passive) clutches can be modulated to improve the overall shift performance. On the other hand, control requirements for such transmissions become more demanding, which calls for the development of new shift optimization and analysis tools.

Methods

First, a shift transient analysis is conducted by using a systematic and illustrative graphical approach based on the bond graph methodology. The bond graph approach is further used to derive a set of conditions for beneficial use of extra, normally-open clutch in the inertia phase of single-transition shifts. Next, a modern numerical optimization tools is used for finding optimal trajectories for transmission clutch input and engine control input. The derived condition-based prediction of beneficial use of extra clutch is verified by comparing the prediction results with optimization results for wide range of shifts.

Preliminary results

The initial results point out that the extra clutch has a potential of significant performance improvement for any single-transition upshift in the inertia phase, in terms of reduced vehicle jerk due to the suppressed inertia bump effect. This is paid for by larger clutch losses during the shift. The optimization results have indicated that the shift quality can also be improved in the torque phase of relatively modest number of upshifts and downshifts, but that improvement is much less emphasized when compared to the inertia phase.

Discussion

The proposed bond graph method can also be applied for analyses of multi-element shifts, which are inherent to advanced ATs. Furthermore, the developed numerical optimization tool can be applied for various optimization-based analysis and design studies of advanced AT shift control.

Acknowledgments

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Keywords

Automatic transmission, shift control, extra clutch, optimization

Stability Analysis of Spatially Distributed Dynamical Systems

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Introduction

One of the main goals in control theory for spatially distributed systems (large-scale dynamical networks) is a development of scalable and efficient stability analysis methods. Stability analysis is a first step towards an even more challenging task of designing controllers for such systems. Since we have to deal with a large number of states and interconnection variables, direct application of classical stability analysis methods on the overall network as a single system would result in a prohibitively high computational complexity. An alternative solution is to find local conditions which, when satisfied separately by the subsystems in the network, guarantee the stability of the overall network. One of the key challenges in such alternative approach is to obtain scalable analysis conditions, which are at the same time not too conservative for practical applications.

Methods

A traditional and often used approach in stability analysis lies within the framework of dissipative dynamical systems which accounts for finding appropriately defined local storage functions, corresponding supply functions and the coupling conditions which together imply stability of the overall network. It can be shown that proving the stability of dynamical networks using static supply rates boils down to finding a Lyapunov function for the overall network where the Lyapunov function is a sum of local storage functions. In this way, structural properties of the dynamical networks can be exploited in order to formulate stability conditions in terms of linear matrix inequalities structured in such a way that they reflect the topology of the underlying interconnection graph. Instead of using static supply rates, in this work we consider usage of less conservative dynamical supply rates which were originally introduced in the general framework of robust control.

Preliminary results

In order to show the added value of the proposed stability analysis methods based on dynamical supply rates, we have considered a stable interconnection of two linear time invariant systems for the case where one subsystem is unstable. Preliminary results show reduced conservatism through comparison of the performance of static multipliers, dynamical multipliers parameterized through the use of basis functions and dynamical multipliers which are piecewise constant functions in the frequency domain.

Discussion

Our primary aim has been to show that dynamic supply rates allow us to tackle stability analysis of dynamical networks in a less conservative way. A novel type of dynamical multipliers, which are piecewise constant functions in the frequency domain, have been introduced allowing us to reduce the computational complexity of the analysis. In particular, we have developed simple algorithms for stability analysis of two interconnected systems, which will be further generalized to stability analysis algorithms for large-scale dynamical networks.

Acknowledgments

This work has been supported by Croatian Science Foundation under the project 9354 Control of Spatially Distributed Dynamical Systems.

Keywords

Stability analysis, dynamical networks, dissipativity

Advanced Model for Long-Term Energy Planning with Application of Multi-Criterial and Multi-Level Optimization

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Introduction

Sustainable development demands a sustainable energy system. Fossil fuels will not be the only energy source choice in a future dominated by renewable energy sources (RES). It is necessary to technologically upgrade the existing energy system with improved methods of energy planning and integration of RES production. For 100% RES system, there is a need for techno-financial optimization to formulate a proper understanding of the problem. Development of the mathematical model and use of optimization brings optimal conditions of use for complex energy systems, with savings in investment, maintenance and operation and greenhouse gasses (GHG) reduction.

Methods

Methodology is based on numerical methods. Basic concept balances the energy system by optimizing the most expensive component, energy storage. Two levels of optimization are employed, primary for determining the capacity of the system, and secondary for planning the utilization of the components, under which a custom merit-order algorithm was developed. Multi-target optimization includes dimensions for minimal installed power, minimum emission of GHG or minimum levelised cost of energy (LCoE). Seasonal role of energy storage was determined to be the crucial factor in balancing the system, for which an extension of the merit-order algorithm was implemented.

Preliminary results

The model was upgraded and expanded from the existing spreadsheet calculation model to a new platform based on C# programming language, including a plug-in optimization framework. Initial research focused on replicating detailed modelling of micro grids and island systems. Secondly, the electric vehicle module was added, bringing capabilities to model dump charge, smart charge and vehicle to grid modes for electric vehicle fleet. Next, desalination via reverse-osmosis was added as a way of demand-side management by deferrable loads and integration of water resources as an energy vector. Finally, modelling concerning urban micro grids and transition to national-level energy systems was implemented. A combination of H2RES model and RenewIslands methodology with Top Energy software for optimization of super-structure of the energy system provided a good balance between pure mathematical optimization and reducing the field of adequate solutions with domain knowledge.

Discussion

The key to a successful optimization method for long-term energy planning with integration of renewable energy sources and storages lies in managing the optimization calculations of energy storages. Brute-force calculations of all possible states for a given energy storage are not feasible as it would consume excessive computational resources and time. The need for hourly calculations needs to translate into a manageable problem regarding energy storages that work on seasonal or even multi-year horizons. The second point of discussion is the optimal solution of multiple energy vector system. While the electricity segment of the system might be optimal, it does not necessarily mean that e.g. the heating segment works optimally. This problem is especially emphasized when dealing with physically separate or loosely connected systems. Therefore, after each time step, a consolidation step needs to be run, to reconcile all subsystems, as the optimum of a subsystem should translate to an optimum of the overall system.

Keywords

Long-term energy planning, multi-objective optimi-zation, energy storage, renewable energy sources

Two-Way Coupled Eulerian-Eulerian Simulations of Drifting Snow

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Introduction

CFD drifting snow models available in the literature are mostly based on one-way couling, which is appropriate for the suspension layer away from the snowbed. In the saltation layer, close to the snowbed where two-way coupling applies, they use empirical correlations of the snow flux, developed for equilibrium conditions. These are inaccurate in urban settings where non-equilibrium prevails.

Methods

A two-way approach is proposed, where both saltation and suspension layers are fully resolved, and no equilibrium assumptions are made. This consists of solving a separate Navier-Stokes system for each of the snow and air phase. These two systems are coupled through momentum, based on the drag and lift forces, which are the dominant forces in aeolian transport of solid particles. A novel viscosity model is also developed for the drifting snow phase, based on conservation of momentum between a group of Lagrangian particles and their Eulerian fluid equivalent.

Preliminary results

The numerical results of the proposed two-way coupled approach are compared to experimental measurements. The new approach is found to accurately resolve the saltation layer if one partice size is taken into account. The new approach accurately resolves the lower suspension layer if a two-parameter Gamma distribution of particle sizes is taken into account.

Discussion

The preliminary results of the two-way coupled approach are a good match to experimental measurements. The particle distribution effect noticed agrees with field and wind tunnel observations of particle size segregation normal to the snowbed. Transport into the upper suspension layer occurs through turbulent lift, which is not yet included in the present approach. Therefore the lack of agreement with experimental measurements in the upper suspension layer is to be expected.

Acknowledgments

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Keywords

Drifting snow, saltation layer, suspension layer, two-way coupling, gamma distribution

Visual Human Resource Management

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Introduction

Evaluation of working positions and formal qualifications of employees is very good tool for visualization of your current state in working performance and ethics. It ensures to see most skilled people in company and let them achieve their full working capacity. In this paper it will be represented how it should be done, and the results from the study on factory for prefabricated concrete elements and sample of 200 people is represented and analyzed. In lean methodology wrong culture that fails to recognize the strengths and contribution of employees is the main reason of slow improvement, and it is proven that skilled employees are drivers for manufacturing competiveness.

Methods

Starting point of this study was to develop method for visualization of workforce competences through simple model of evaluation workforce competences and skills. Model for evaluation of potential of workers was based on quantifying their formal school qualification degree and present working position. Croatian Qualifications Framework (CROQF) was taken as referent point where workers formal competences were measured and quantified. Croatian model of evaluation school degree has scale of measurement from 1 to 8.2 where workers with elementary school degree are awarded with lowest rank 1, and workers with highest academic degree are awarded with rank 8.2. However, in Croatia every big company has its own list of working positions and minimum formal school qualification to handle with job tasks. Ultimate goal in this model for visualization of workforce competence and skills was to collect all data's about individual workers formal qualification and present working position, then quantifying it and in the final step measuring deviation between formal qualification and present working position.

Preliminary results

Preliminary results had proven lack of competences on all levels. Most perceived lack of competences where found on work positions for all kind of workshop craftsman's. This data was disturbing because main production activities are closely connected to such working positions. Conclusion was that manufacturing processes are probably not very well organized, so there is a lot space for improvement of manufacturing activities and reduction of labor costs.

Discussion

Recent studies have presented clear evidence of the relationship between human capital qualifications and competitiveness. Skills and competences are major building blocks of the learning process. Studies have considered and validated "skills" as one of the drivers for manufacturing competitiveness. This method for visualization of workforce in human resource management is very fast and all kind of analysis could be done on collected data. This method was done on CROQF, but it could be done on some other framework. It was visible in begging of this research that this method will bring some interesting data about workforce competences and skills. Obtained results from this research are quantitative and measurable, so they could be compared with data in next iterations of improvement in human resource management.

Keywords

Human resource management, visual management, manufacturing competence

Traceability Assurance in Computed Tomography Dimensional Measurements

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Introduction

Computed tomography is a well known method discovered in 1970s and first applied in medicine. From 1980s it is applied in material analysis for inspection of pores and inclusions and from 2005 on was introduced as a new method for dimensional measurements. It is a non-contact and non-destructive method that uses X-ray to obtain information of both external and internal geometry of measurement objects. Because of the fact that it is a relatively new measurement method, some limitations in its usage are still present. The biggest disadvantages are lack of measurement uncertainty and metrological traceability. Many researches are done at the moment to address this matter. To assure measurement uncertainty and define metrological traceability, all parameters influencing the system should be identified, investigated and described. Influencing parameters can be divided into different subgroups, e.g. depending on the process where they occur. In that case parameters can be divided to: parameters influencing scanning process, parameters influencing reconstruction process, parameters influencing measurement process, or on the other hand a more common division to hardware related parameters, software parameters, environmental parameters, parameters of measured part and operator depending parameters.

Methods

First step in investigation of influencing parameters was research of two parameters which depend on the choices that operator makes during measurements. Two independent experimental researches were conducted where first research dealt with how change in projection number affects measurement results and second research included observing the impact which geometrical magnification has on measurement results.

Preliminary results

First research showed that obtained results are closer to reference value if larger number of projection images is chosen. Observed were situations with 12, 36, 180, 360, 540, 720, 1000 projection images. It was also noted that when increasing number of projection images, there is a point where further enhancement of result is insignificant. Second research showed that magnification is important parameter which influences measurement results in different way depending on observed characteristics.

Discussion

Computed tomography as a metrological tool enables non-destructive measurements of outside and inside geometry and is therefore very interesting for application in many different fields and industries. Its main disadvantage is lack of metrological traceability, and for that reason further researches, with aim to assess measurement uncertainty, are necessary. Thereof, further researches should take into consideration the influence of other parameters as well as assessment of measurement uncertainty according to new revised GUM standard.

Keywords

Computed tomography, Measurement traceability, Measurement uncertainty, Influence parameters

Modeling of Damage Phenomena Using Higher-Order Finite Element Formulation

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Introduction

It is well-known that damage phenomena cannot be objectively modeled by using the classical continuum theory because the differential equations which describe the deformation process may lose the elliptic characteristic once the damage is initiated. Mathematical description of the model in that case becomes ill-posed and numerical solutions do not converge to a physically meaningful solution. To overcome these problems, most of the regularization techniques developed are based on the improvement of the classical continuum model by its enrichment with the internal length scale parameters in various forms. Among these techniques especially nonlocal theories are known, which have been shown to be the most versatile. One of them is the strain gradient continuum theory, which introduces the nonlocality in the model through additional gradient term in the strain energy density function.

Methods

In this contribution, the two dimensional C^1 continuity triangular finite element based on the aforementioned strain gradient theory is extended to the modeling of damage and strain localization phenomena. The linear elastic material behavior is considered, where the linear and exponential damage evolution laws of quasi-brittle damage are employed. Stiffness degradation in the softening stage is governed by the isotropic damage law, where the damage variable in a point of the material depends on the highest value of equivalent elastic strain ever reached in the deformation history. Constitutive matrices are obtained prior to the softening analysis using the second-order homogenization procedure applied on the appropriate representative volume element (RVE). The deformation responses of both homogeneous and heterogeneous materials are investigated. The latter is done by varying the sizes of the adequate RVEs, considering only the academic examples of heterogeneous materials.

Preliminary results

The verification of the presented damage model is made on a benchmark example consisting of a rectangular plate with an imperfect zone under tension. The results obtained are compared with the solutions from the literature, where the same numerical example is analyzed employing the EFG meshless method and assuming only homogeneous materials. Here, the study of damage behavior of heterogeneous materials is made as well. Besides, an analysis of the shear band formation along an imperfect plate subjected to compressive load is performed, and the solutions are compared with the experimentally obtained data.

Discussion

It is demonstrated that strain localization and softening phenomena can successfully and efficiently be captured by means of the proposed computational strategy. In addition, sufficiently accurate model for the softening analysis of heterogeneous materials on the macrostructural level is obtained in a rather simple way. The further research will be concerned with the damage consideration on the microlevel, where a multi-scale computational strategy will be employed.

Acknowledgments

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Keywords

Damage modeling, C1 continuity finite element, Strain gradient theory, Heterogeneous material

Aerodynamic and Aeroelastic Characteristics of Cable-Supported Bridges with Roadway Wind Barriers

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Introduction

Vehicles on bridges prove to be particularly sensitive to cross-winds, which deteriorate their dynamic stability. Hence, wind barriers are developed to protect vehicles from cross-wind effects. While these barriers proved to be successful in sheltering vehicles on bridges, their influence on bridge dynamic stability is not well known. Thus, experimental research on influence of roadway wind barriers on aerodynamic and aeroelastic characteristics of three different types of bridge-deck sections is carried out in collaboration with the Institute of Theoretical and Applied Mechanics in Prague. Wind-tunnel models of bridge sections are studied for various wind barrier height and porosity using the experimental mechanisms for advanced aeroelastic and aerodynamic tests.

Methods

Research activities include experimental work and computational simulations. In this period of research, the focus is on wind-tunnel experiments. During the experiments on bridge-deck dynamic response, the bridge-deck models are placed on the custom-made mechanism for measurements of complex aeroelastic phenomena. Experiments are carried out using the free-vibration method. For measurements of aerodynamic force and moment coefficients experienced by bridge-decks, an experimental mechanism for separate measurements of aerodynamic forces and moments is designed. Flow characteristics downwind from the bridge-deck models are measured using the CTA (Constant Temperature Anemometer) device. Flow field around the bridge-deck section models is obtained using the PIV (Particle Image Velocimetry) technique.

Preliminary results

Dynamic stability of studied bridge-decks proved to be deteriorated while the critical flutter wind velocity is reduced when wind barriers are placed on bridge decks. The influence of wind barriers is more pronounced for streamlined bridge-deck sections. A decrease in porosity of wind barriers increased the susceptibility of studied bridge-deck sections to dynamic instability. Aerodynamic drag force of bridge-decks is increased when wind barriers are placed on bridge-decks, while wind barriers proved not the influence galloping instability that is based on the results of the Glauert – Den Hartog criterion.

Discussion

The experimental results indicate an exhibited influence of roadway wind barriers on aerodynamics and aeroelasticity of studied bridge-deck sections. Wind barriers present an additional obstacle to the wind flow and create an increased flow pressure on the leading edge of bridge decks. Bridge decks with wind barriers experience negative aerodynamic damping in torsional motion at certain wind velocity, thus the net damping of the system (consisting of aerodynamic and mechanical damping) is reduced. Therefore, bridges with wind barriers could become dynamically unstable in torsional motion, thus indicating an adverse effect of wind barriers on torsional flutter.

Acknowledgments

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Keywords

Bridge deck. Roadway wind barrier. Aerodynamics. Aeroelasticity. Wind-tunnel experiments

Modeling of Material Deformation Responses at Nanolevel

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Introduction

So far continuum mechanics has been dominate method for studying behavior of the material under load. However usual formal approach of continuum mechanics needs a series of constitutive equations that are result of phenomenological approach to the material deformation process. Variables that we notice in conventional experiments, that are part of constitutive relations, are the consequence of dynamics of an extremely large number of atoms. In atomistic model changes in nanostructure of material are simulated by using molecular mechanics (MM) founded on experimentally and theoretically adjusted interaction of atoms. In that system atoms are regarded as a dynamic system of particles governed by Newton's laws. The goal is to find influence of individual properties at the atomistic level and interpret them correctly into the macro level.

Methods

Using MM methods 2D crystal lattice is modeled by writing own code in the software surroundings of MATLAB. For describing interatomic interactions pairwise Lennard-Jones (LJ) potential is used. To simulate bulge of crystal correctly periodic boundary conditions (PBC) are applied on all edges of simulation box. For finding metastable configurations of atoms, which corresponds with positions of local minima of potential energy at temperature of absolute zero steepest descent, conjugate gradients and Newton-Raphson iterative procedures were used. After studying properties of perfect crystal lattice influence of voids and dislocations inside the crystal is analyzed. For studying properties of the system at finite temperature Verlet algorithm is used as a numerical time integrator.

Preliminary results

By analyzing different crystal structures at temperature of absolute zero metastable configurations of atoms for each type of imperfections are acquired. In addition to the different equilibrium configuration, change in potential energy, in comparison with ideal lattice, can be seen. During deformation of the crystal by imposing edge displacement of the simulation box increase of the strain energy has been noticed. As expected stress at the edges of the simulation box during deformation rises with the increase of initial imperfections inside the crystal.

Discussion

The aim of the first part of research is to develop simple academic model of crystal which is suitable for assessment of important parameters of nanolevel onto observable macrolevel values. By using simple LJ potential focus can be placed on structural phenomena like dislocation. It has been show that using MM certain properties, like energy, stress and elasticity modulus, of the materials at nanolevel can be obtained. In the further research analysis of the atomistic model will be extended onto identifying suitable damage variable which will enable coupling of atomistic and continuum model.

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Keywords

Atomistic modeling, Molecular mechanics, Damage

Workflow Development for Agent-Based Simulation of Design Teams

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Introduction

Project managers involved in engineering systems development need support in the form of methods and tools that will help them deal with challenges arising from such as selection of optimal team composition, planning of the work activities, and early identification of project risks. Manager's perspective can be improved with insight into team's interaction and knowledge networks, team's shared mental model, and individual's characteristics such as social skills, learning ability, availability, response rate, motivation, etc. Development of methods and tools for gathering such data requires monitoring and measurement of individuals and teams performance within different stages of product development process.

Methods

This research explores simulation as a management tool to help managers in the planning of team composition and activities and investigate if project planning could be enhanced by relative performance comparison of teams composed of different individuals working within different types of development projects. Both points of interest provide the need for a simulator of development processes in which individuals are simulated to work and interact in teams and perform individual and teamwork activities. It is desirable to monitor and measure individual and team performance for a larger number of participants across different contexts. Combining results of longitudinal and empirical studies with the advances in information technologies opens a space for utilizing simulations (more precisely agent-based modeling) of teamwork in development processes as a potential research and management tools.

Preliminary results

The first step in simulating development processes was the development and implementation of a predefined workflow within an agent-based model, so agents could follow and solve a set of project tasks. The process of solving such tasks includes both individual work and teamwork (discussion, learning and providing help). The simulation generates data that describes how agents spend their time, how their competences and skills change, and how they interact and collaborate.

Discussion

Simulation model validation started by comparing generated outputs with data collected on a sampled industry project. The next step will include development and implementation of different process types that can be extracted from the literature and empirical studies that will help to describe specific activities within the process. Thus it will be possible to simulate projects with different resources, complexity and innovation level. This will eliminate predefined workflows and provide the flexibility needed before the simulation model can be used as a project planning tool.

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Keywords

workflow design, product development process, teamwork simulation

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