University of Patras
Department of
Mechanical Engineering and Aeronautics

Diploma Thesis

Academic Year
2024-2025

Patras, Greece

CONTENTS

INTRODUCTION

The Diploma Thesis (DT) is an important component of a student's education. Its purpose is to give the student the opportunity to work in a scientific manner, utilizing both the general and specialized knowledge acquired during their studies in the Department of Mechanical Engineering and Aeronautical.

The aim of DT is to offer the student the chance to delve into a subject of particular interest to them, which will introduce them to the corresponding field of application and research, and may even serve as the first step towards a related professional and research career.

It carries thirty-six (36) ECTS credits and fifty-five (55) teaching units, and its successful completion, presentation, and grading are essential prerequisites for graduation. The thesis is registered in the ninth and tenth semesters of study, and its execution lasts at least two semesters.

The student, after consulting with a professor or an E.DI.P. (Special Laboratory Teaching Staff) member they wish to collaborate with, selects the thesis topic, and a three-member committee is appointed to oversee the work. The student then applies to the Department's Secretariat for the approval of the thesis supervisor, the topic, and the three-member committee by the Department Assembly. Upon approval by the Assembly, the student can begin their thesis work.

Regarding the content, the diploma thesis must include the following:

- **Literature Review**: A thorough review aimed not only at citing previous work but also providing a critical and synthetic assessment of the research done to date in the scientific field of the thesis topic.

- **Topic Analysis**: This section should outline the problem being addressed, describe the methodology used for solving it, and include details of the experimental and/or analytical, numerical techniques applied, as well as the experimental and/or computational tools used.

- **Results**: The outcomes of the research, the conclusions drawn, and suggestions for future work.

Thesis presentations are held three (3) times a year after the exam periods in June, September, and February, during scheduled open sessions of the Department, on dates and with a program determined by the respective directors. During the presentations, the results of the theses are displayed in A3-sized poster form.

The goal of this booklet is to showcase the results of the theses completed in the Department over recent years.

Below are the abstracts of each thesis.

DIVISION OF APPLIED MECHANICS, TECHNOLOGY OF MATERIALS AND BIOMECHANICS (FEBRUARY 2025)

DEVELOPMENT OF OPEN CELL STRUCTURES BY INVESTMENT CASTING OF ALUMINIUM ALLOYS USING ADDITIVELY MANUFACTURED POLYMERIC MODELS

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ABSTRACT

Lattice structures are complex architected cellular structures made up of an interconnected network of struts, plates or surfaces that can be engineered to comply to a certain shape, weight, load and deformation profile. Metal lattice structures have been historically very challenging to manufacture due to their complexity, though recent advances in Additive Manufacturing (AM) or 3D printing of metal components have made producing them and studying them much more feasible. However, metal AM processes are still relatively expensive and inaccessible and exhibit problems controlling their structure on the macro and micro scale.

Investment metal casting on the other hand is a much more mature and accessible process that offers excellent dimensional and structural control. However, until recently manufacturing investment casting molds presented a serious hurdle as it required the injection molding of a sacrificial negative wax model of the mold using machined or cast metal dies which are relatively involved and expensive components to manufacture.

Advances in the AM of polymeric materials have come to solve this problem. The price of 3D printing polymeric materials has decreased significantly in the recent years, with Fused Filament Fabrication (FFF) or Fused Deposition Modeling (FDM) 3D printers becoming

ubiquitous. As such, substituting the injection molded wax pattern for a FFF printed one can help reduce the cost and complexity of investment casting process significantly.

In this study an investment casting process for aluminium lattice samples using 3D printed polymeric models is presented. This process includes the generation of the lattice structures using implicit modeling, the mold manufacturing using the FFF printed PLA models, including the burnout and curing of the molds, and finally the casting with the assistance of a vacuum table. The cast lattice samples are then scanned using an μCT Xray tomography machine to examine their internal structure and their dimensional accuracy compared to the original model. Finally, they are tested under compression and compared to a Finite Element Analysis (FEA) model to reveal their mechanical properties.

Keywords

Lattice Structures, Additive manufacturing, 3D Printing, FFF Printing, Investment Casting

DEVELOPMENT OF EXPERIMENTAL SETUP AND EXECUTION OF EXPERIMENTAL TESTS AT CRYOGENIC TEMPERATURES

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ABSTRACT

The need for new technologies to solve problems facing society, but also to improve existing ones, brings cryogenic applications to the foreground. That is, applications that take place at temperatures below -100°C and can even approach absolute zero (-273°C). One of the most important cryogenic applications is the design and construction of liquid hydrogen storage tanks as a future fuel for the aviation and space industry. The challenge in such applications is to achieve and maintain the extremely low temperatures required. Thus, it is essential to investigate the properties of materials at such extreme temperatures and then select the most suitable ones to meet the requirements.

In this thesis, a study of the properties, mainly of composite and polymer materials, is carried out and the experimental tests, according to which the mechanical properties of these materials are examined, are presented. Then, the two experimental setups, developed in the laboratory, for conducting compression experiments at low temperatures and at liquid nitrogen temperature respectively, are presented. In the context of this work, a series of experiments with PEEK polymer material is carried out, aiming first to test the reliability of the devices and then to study the mechanical properties of PEEK, since it presents very good characteristics at low temperatures according to the literature. The experimental procedure followed is presented, as well as the results obtained from the experimental tests. In summary, the compressive strength and the compressive modulus of the material increase with decreasing temperature, results that agree with those of literature.

Finally, the aim of the present work is to provide a basis for future research, so that it will be possible to carry out experiments at lower temperatures, such as that of liquid hydrogen (-252°C), but also of different types, such as tensile, impact etc.

Keywords

Cryogenic applications, Liquid hydrogen, Composite materials, Polymer materials, Experimental tests

INVESTIGATION OF MECHANICAL PROPERTIES OF MATERIALS IN CRYOGENIC CONDITIONS

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ABSTRACT

The need for cooling of mechanical systems and materials at cryogenic temperatures occurs in various applications, which have gained intense scientific interest in recent years. In particular, when attempting to utilize cryogenic fluids as fuels in areas such as aviation, the issues of transport, storage and safe utilization arise. The engineering of cryogenic applications is still an evolving discipline. Therefore, further research is needed to develop cooling processes for systems with cryogenic operating conditions and to characterise materials in this temperature range.

In this thesis, a literature review of the behaviour of some materials at cryogenic temperatures is firstly carried out as candidates for the construction of cryogenic storage and transport tanks. In particular, the behaviour of some metals and polymers is studied, with emphasis on the behaviour of fibre-reinforced composites as candidate future materials for use in cryogenic conditions. Next, a description of the experimental setup developed for conducting compressive experiments at ambient and low temperatures for the characterization of polymeric materials is given. Compression tests at ambient and low temperatures (-20 ^{o}C, -50 ^{o}C, -80 ^{o}C) were carried out on Polytetrafluoroethylene (PTFE) specimens to characterize the material, specifically its strength and modulus properties. To verify the reliability of the results, additional tests were carried out to calculate the machine's compliance, both at ambient and low temperatures. The results from the experimental tests are evaluated at the end of the paper and compared with the findings of the literature, and some conclusions are also presented.

From the results obtained, it is concluded that the ASTM D695-15 specification can be used to determine the compressive properties of the polymer at both ambient and low temperatures. Furthermore, it is found that the change in the properties of Polytetrafluoroethylene (PTFE) polymer observed during the experimental tests is in agreement with the findings in the

literature. Finally, it is deemed necessary to conduct additional tests for the characterization of other materials such as composites, while it is also deemed necessary to design and construct experimental setups to conduct tests at even lower temperatures.

Keywords

Cryogenic Temperatures, Composite Materials, Polytetrafluoroethylene, Compressive Strength, Modulus of Elasticity

CONCEPTUAL DESIGN OF A UAV FOR FIRE SUPPRESSION

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ABSTRACT

The design of unmanned aerial vehicles (UAVs) with vertical takeoff and landing (VTOL) capability has not yet established an automated methodology, as seen in conventional aircraft design. This thesis focuses on the design of a UAV capable of lifting a 1-ton payload, contributing to the development of a methodology for UAV design across various sizes, with an emphasis on firefighting applications.

A literature review was conducted on both manned and unmanned systems, as well as firefighting aircraft, providing valuable data on the technical specifications and performance of conventional and coaxial rotors. The research highlighted the need for aircraft with greater payload capacity to meet the requirements of transporting large amounts of water for firefighting.

In this context, an investigation was conducted on the impact of fuel weight for internal combustion engines and battery weight for electric motors, aiming to design a lightweight UAV capable of carrying a larger payload. Internal combustion engines offered advantages in terms of autonomy and payload capacity, while electric motors provided environmental benefits and reduced noise levels.

The conceptual design included a large UAV with specifications similar to the Bell UH-1H HUEY, incorporating both conventional and coaxial rotor configurations. In the coaxial system, geometric parameters such as rotor diameter and rotor interaction were examined, while a reduction in overall length was calculated due to the absence of a tail rotor. The final design was evaluated for firefighting applications using data from existing systems.

The comparison between conventional and coaxial rotors showed that coaxial rotors provide a 13% higher efficiency in hover, due to the increased active disk area and improved

aerodynamics, along with an additional 10% improvement across all flight phases due to the absence of the tail rotor.

To leverage these findings, we developed a new approach that considers the different flight phases hover, climb, and forward flight allowing for a more detailed and accurate calculation of the total weight.

Finally, we evaluated the methodology we developed by comparing the three models A, B, and C, which were designed with specifications similar to those of the Birotor Coaxial High Capacity Helicopter, Ultra 2XL – Heavy-Lifting Drone, and Combo. The comparison focused on their weights, aiming to analyze the deviations between the calculated and actual data. Ultimately, we finalized the design of our UAV, based on the specifications of Model C, with a payload capacity of 1100 kg, and developed its flight profile for a 3.4-hour mission.

Keywords

Unmanned Aerial Vehicles, Conventional Rotor, Coaxial Rotor, Vertical Take-Off and Landing, Firefighting.

MAIN WING DESIGN, ANALYSIS AND OPTIMIZATION OF A NOVEL UNMANNED AIR VEHICLE

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ABSTRACT

The thesis examines the design, analysis, and optimization of the main wing of an unmanned aerial vehicle (UAV), focusing on aerodynamic performance and structural integrity. The study includes theoretical analysis and the practical application of computational simulation techniques, aiming to create an efficient and innovative design. The primary objective of the UAV is payload transportation; therefore, the design is based on this operational requirement. Material selection emphasizes composite materials, such as carbon fiber, which offer a combination of lightness and rigidity. The aerodynamic characteristics of the wing are optimized to achieve maximum lift with minimal drag. Aerodynamic analysis is conducted using Computational Fluid Dynamics (CFD) to model the airflow around the wing, specifically through the computational packages XFLR5 and ANSYS FLUENT. The results reveal critical data regarding airflow, pressure distribution, and drag patterns. Subsequently, the Finite Element Analysis (FEA) method is applied using the ANSYS Mechanical computational package to evaluate the structural strength of the wing under loads during specific flight phases. Ultimately, this study is expected to contribute to the advancement of scientific knowledge in the field of UAVs and serve as a valuable tool for future applications of these systems.

Keywords

UAV, Canard, FEA, CFD, optimization

MECHANICAL AND FRACTURE CHARACTERIZATION OF EPOXY NETWORKS, USING ATOMISTIC SIMULATIONS

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ABSTRACT

In recent years aerospace companies have dramatically increased the use of composite epoxy materials, reaching 50% of the total weight of the aircraft. Mainly, due to their very light weight compared to their high strength, combined with very good mechanical properties, such as fracture toughness. Furthermore, they withstand high large plastic deformations over a wide temperature range. Epoxy materials are created by curing, which includes polymerization, of epoxy resins with hardeners under specific conditions.

Their study is taking place at the microscopic level, with the help of Molecular Dynamics, allowing the analysis of the microstructure of the molecular system, the hardening mechanisms and finally extracting the macroscopic properties of the material.

Molecular Dynamics bridges the gap between the microscale and the macroscale, based on the principles of statistical mechanics. It is a computational method of analysis the motion and the interactions of atoms and molecules, based on Newtonian Mechanics. The forces between particles are expressed in terms of potential energy, which is calculated with the help of packages which are called force fields. In classical molecular dynamics, a finite-mass point replaces the three-dimensional structure of the atom. The balance between repulsive and attractive forces defines the potential energy between atoms; that consists the force field. The user has to choose between a plethora of force fields, depending on the simulation being performed. In force fields the potential energy is expressed by harmonic and non-harmonic oscillators. With their contribution atomic interactions are described, which are divided into bonded interactions (bonds, angles, dihedral angles and improper dihedral angles) and non-bonded interactions (Coulomb, van der Waals). Newton's equations of motion are then applied and the trajectories of the particles are derived. Molecular Dynamics is widely used in physics, chemistry, biology and materials science to study the mechanical, thermal and chemical properties of the system, capable of simulating the formation and decomposition of chemical bonds reactions with great accuracy. One of the most used programs that implement the science of molecular dynamics is the open source Large-Scale Atomic/Molecular Massively Parallel Simulator (LAMMPS), the best existing for material science simulations.

The presented work studies the crosslinking of molecules of the epoxy resin Diglycidyl Ether of Bisphenol F (DGEBF) with molecular formula $C_{19}H_{20}O_4$ and the hardener Diethyl toluene diamine (DETDA) with molecular formula $C_{11}H_{18}N_2$, with final purpose the creation of an epoxy material system. The crosslinking process is based on the REACTER protocol. The whole algorithm, the selection of the necessary settings and parameters which the user has to choose and modify to obtain the best results is explained. The simulation of the crosslinking of epoxies and hardeners is accompanied by several difficulties and challenges, the main one being the very high computational cost, which is primarily depending on the chosen force field and the simulation time, which is on the scale of nanoseconds.

Concluding, in this study firstly is presented the algorithm the user has to follow in order to construct a crosslinked system, balanced in terms of energy and structure, with a satisfactory density and crosslinking degree which approximates the experimental values. In the end, the system is ready to undergo more simulations so the user can investigate its mechanical properties.

Finally, is presented the algorithm for fractural analysis of epoxy networks, as well as data analysis to extract the mechanical properties of such systems. The study focuses on (i) studying the dependence of mechanical properties on the crosslinking degree of the network and (ii) size study in order to investigate the optimal epoxy network size that combines accurate results and computational efficiency.

Keywords

Molecular Dynamics, Simulations, Crosslinking, Atomic interactions, Epoxy Materials, classical Force Fields, LAMMPS, DGEBF, DETDA, Fractural Analysis, Mechanical properties.

DESIGN, ANALYSIS AND OPTIMIZATION OF SECONDARY WING OF A NOVEL UNMANNED AIR VEHICLE

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ABSTRACT

This thesis focuses on the structural development and analysis of the Canard wing of an unmanned aerial vehicle (UAV) using the finite element method (FEA). The aerodynamic analysis and conceptual design of the aircraft have already been conducted as part of a previous study, allowing this research to focus exclusively on the mechanical strength and structural optimization of the wing.

Initially, the structural model of the wing is developed, incorporating the primary load-bearing components such as the spar, ribs, and skin, while selecting appropriate high-strength, lightweight materials like carbon fiber reinforced polymers (CFRP) and PETG-Carbon.

Subsequently, static and dynamic analyses are conducted using ANSYS software, evaluating stress distribution, displacements and critical loads. Different loading conditions are examined, including hovering, 4G flight acceleration, and buckling analysis, to ensure structural integrity and resistance under real-world operational conditions.

Finally, the analysis results allow for the optimization of geometry and material distribution, minimizing weight without compromising structural strength. This study contributes to the development of a Canard wing capable of meeting UAV performance requirements, ensuring both aerodynamic efficiency and structural reliability.

Keywords

Unmanned aerial vehicle, aerodynamic analysis, airfoil, stability, conceptual design, finite element analysis

MACHINE LEARNING-DRIVEN DELAMINATION DETECTION IN COMPOSITE BEAMS

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ABSTRACT

This thesis focuses on the development and evaluation of machine learning algorithms for predicting the delamination percentage in composite materials. Composite materials are widely used in critical industrial applications due to their high strength-to-weight ratio and durability, yet they are susceptible to internal damage, which is not always detectable using conventional inspection techniques. Predicting such damage is a critical challenge within the framework of Structural Health Monitoring (SHM), where artificial intelligence (AI) methods can provide faster and more accurate solutions. To train the machine learning algorithms, a dataset was created based on numerical simulations using the Finite Element Method (FEM). The simulations were conducted in Fortran, where various delamination scenarios with different damage percentages and geometric configurations were examined. The simulation output included dynamic responses, which were then used as input features for the machine learning models. Subsequently, various machine learning algorithms were implemented and compared, including Linear Regression, Random Forest, Gradient Boosting, Multi-Layer Perceptron (MLP), and Long Short-Term Memory (LSTM). Their performance was evaluated using metrics such as Mean Squared Error (MSE) and the coefficient of determination (R^2). Additionally, the generalization ability of the models was assessed by testing their predictions on unseen data and experiment data. This research highlights the potential of machine learning techniques in predicting structural damage in composite materials, contributing to the development of automated diagnostic systems. Future research could focus on expanding the methodology to predict additional damage characteristics, such as delamination location and depth, which would further enhance the accuracy and applicability of AI-driven SHM systems.

Keywords

Machine Learning, Delamination, Composite Materials, Structural Health Monitoring, Finite Element Method.

SURROGATE MODELLING OF ADDITIVE MANUFACTURING OF METAMATERIALS

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ABSTRACT

Lattice structures belong to the metamaterial family which are artificially made materials with mechanical properties that are not found in natural materials. They have gained popularity in recent years due to their attractive mechanical properties and the advancements in AM technologies. Changing the geometry and material parameters of a lattice RVE changes the effective mechanical properties of it. This possibility to alter their mechanical properties allows the mechanic to tailor them for case-specific designs. This study focuses specifically on the Body Centered Cube (BCC) lattice element. This is a very interesting type of unit cell geometry as it combines a very easy to manufacture geometry with structural efficiency.

Finding the best design for a case-specific problem is accomplished through an optimization problem, which is a mathematical framework that allows for easy location of the optimal design by scanning the design parameter range. This thesis aims to solve a multi-objective optimization problem focuses on the BCC lattice RVE. The goal is to simultaneously minimize the weight of the RVE (important for lightweight applications) and the deflection of the struts of the BCC RVE under compressive load (important for maintaining structural integrity). The optimization problem is solved using a genetic algorithm (specifically in this thesis MOGA II).

Three different models are created for the purpose of solving the optimization problem, each with its own advantages and limitations. The first model uses analytical expressions, providing a fast and intuitive way to approximate the RVE's behavior under load. The second model utilizes Finite Element Analysis (FEA), significantly improving accuracy but at the cost of increased computational time. Given the high computational demands of FEA-based optimization, a surrogate model (metamodel) trained on FEA results is introduced. This metamodel acts as a virtual optimization tool, replacing direct FEA evaluations with AI-based predictions, drastically reducing computational cost and runtime.

The results highlight the strengths and limitations of each approach, show- 1 casing the trade-offs between accuracy, computational efficiency, and generalization capabilities. This exploration of modeling trade-offs provides valuable insights into how different approaches can be used for lattice structure optimization in future work.

Keywords

Lattice, Optimization, RVE, Surrogate Model, Metamaterial

DESIGN, ANALYSIS AND OPTIMIZATION OF H2 STORAGE TANK

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ABSTRACT

This thesis presents a comprehensive study on the design, analysis, and optimization of composite hydrogen pressure vessels (CPVs) for advanced hydrogen storage applications. With the rising demand for sustainable energy and the increasing role of hydrogen as a clean fuel, this research addresses the critical challenges in developing safe, efficient, and lightweight storage solutions, particularly for the automotive industry. The work begins with a thorough introduction to hydrogen—its properties, advantages as an alternative fuel, and its application in internal combustion engines and fuel cell technologies. A detailed review of various hydrogen storage methods is provided, ranging from mechanical storage, solid-state storage, liquid hydrogen, and cryo-compressed hydrogen, to chemical storage. This broad overview establishes the context for selecting composite materials as a superior alternative for pressure vessel construction.

A significant portion of the study is dedicated to composite materials, highlighting the characteristics of both fiber and matrix constituents. Emphasis is placed on the manufacturing techniques critical to achieving high-performance CPVs, such as the filament winding method, prepreg tape application, and advanced composite lay-up processes. The selection of these techniques is justified by their ability to optimize the strength-to-weight ratio and enhance the overall structural integrity of the vessels. Focusing on Type V CPVs—fully composite pressure vessels—the thesis develops a robust analytical framework to evaluate their mechanical behavior under high-pressure conditions. The study employs classical laminate theory, netting analysis, and grid theory to predict stress and strain distributions within the vessel walls. Additionally, advanced failure criteria, including the Tsai-Wu, Tsai-Hill, Von Mises, and Hashin models, are utilized to assess potential failure modes and ensure the vessel's reliability under operational loads.

To validate the analytical models, finite element analysis (FEA) is conducted. The FEA process involves creating detailed geometric models, defining appropriate mesh configurations, and applying realistic boundary conditions and load cases. The simulation results, which capture the complex interactions between material properties and structural responses, are compared with theoretical calculations of burst pressure to verify the accuracy of the design. Optimization strategies are then applied to refine the CPV design, focusing on adjusting filament winding patterns and composite lay-up configurations to achieve an optimal balance between material efficiency and mechanical performance. The resulting design not only meets stringent safety and regulatory standards but also demonstrates significant improvements in performance and durability compared to conventional metallic vessels.

In conclusion, the research provides compelling evidence that advanced composite materials, when coupled with optimized design and analysis techniques, can effectively address the challenges of high-pressure hydrogen storage. The insights gained from this study contribute to the development of next-generation hydrogen storage systems, paving the way for their broader application in the automotive and energy sectors.

Keywords

Composite pressure vessels, Progressive damage, Hashin damage criterion, Failure modes, Thermoplastic materials, Compressed hydrogen storage.

DEVELOPMENT OF RECYCLABLE CROSS-LINKED POLYMERS FOR APPLICATION IN FIBROUS COMPOSITE MATERIALS

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ABSTRACT

This thesis explores the development, characterization, of Carbon Fiber Reinforced Vitrimer Composites (CFRV), a novel class of recyclable and reprocessable materials. Vitrimers, a type of polymer with dynamic covalent bonds, enable the manufacturing of composites that combine the high performance of traditional thermosets with the recyclability of thermoplastics. The study focuses on comparing the mechanical properties of CFRV with conventional Carbon Fiber Reinforced Polymer (CFRP) composites, aiming to demonstrate the viability of vitrimer-based composites as sustainable alternatives in structural applications.

The theoretical part of the thesis provides a comprehensive overview of composite materials, emphasizing their classification based on reinforcement type (fiber, particle, and structural composites) and matrix type (ceramic, metallic, and polymeric). It also delves into the chemistry of vitrimers, highlighting their unique dynamic covalent networks, which allow for reprocessing, self-healing, and recycling without compromising mechanical integrity. The vitrimer matrix used in this study is based on Vitrimax epoxy resin and an imine-based hardener, which undergoes reversible exchange reactions at elevated temperatures.

The experimental part involves the fabrication of CFRV and CFRP composites using a prepreg-based approach. The CFRV prepregs were produced by impregnating carbon fibers with the vitrimer resin, followed by curing in an autoclave. Mechanical testing, including three-point bending (ASTM D7264) and short beam shear (ASTM D2344), revealed that CFRV outperformed CFRP in flexural strength (22.68% higher), flexural elastic modulus (6,7 % higher), and interlaminar shear strength (1.72% higher). Additionally, CFRV demonstrated excellent shape reformation at 130°C and recyclability through dissolution in a butylamine/xylene solution, enabling the recovery of carbon fibers.

The study concludes that CFRV composites offer a sustainable and high-performance alternative to traditional CFRP, with the added benefits of recyclability and reprocessability. These findings pave the way for the adoption of vitrimer-based composites in industries requiring lightweight, durable, and eco-friendly materials, automotive, and sports industry. Future work will focus on optimizing the vitrimer formulation for specific applications and scaling up production for industrial use.

Keywords

Vitrimers, Covalent Adaptable Networks, Composite Materials, Recycling, Epoxy Resins.

COMPUTATIONAL SIMULATION OF THE AEROELASTIC BEHAVIOUR OF A SIMPLIFIED WING PROTOTYPE EQUIPPED WITH PIEZOELECTRIC SENSORS

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ABSTRACT

This Diploma Thesis deals with the development of a computer model for the simulation of the aeroelastic behaviour of a wing, the study of that behaviour and the incorporation of piezoelectric sensors. Initially, sections of structural analysis theory, aerodynamic theory and piezoelectric phenomenon theory are mentioned. Relevant literature of similar models and applications is highlighted. The structural modeling method, i.e. two-node finite elements with three nodal degrees of freedom (w,β_x,β_y), the consideration of the wing as a cantilever Timoshenko beam, and other assumptions are explained and justified. Accordingly, the aerodynamic modelling method, i.e. the modeling assumptions, the calculation of aerodynamic quantities and the calculation of the aerodynamic forces, is explained. The results of the computational experiments combined with the corresponding theory demonstrate the need to redefine the structural model of the wing, so a new structural model is created. New computational experiments are carried out, the results of which are analyzed to draw conclusions, regarding the aeroelastic behaviour of the wing. Finally, a model is built to incorporate a piezoelectric sensor on the wing surface in order to measure its mechanical behaviour.

Keywords

Structural Dynamics, Aerodynamics of Wings, Computational Model, Aeroelastic Behaviour, Piezoelectric PVDF Sensor

DESIGN, ANALYSIS AND OPTIMIZATION OF A NOVEL UNMANNED AIR VEHICLE FUSELAGE

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ABSTRACT

The present Thesis focuses on the design, analysis and optimization of the fuselage of a canard-type Unmanned Aerial Vehicle (UAV). This specific configuration is chosen based on the desired operational requirements we specify and the targeted performance for long-range and high-maneuverability flights.

The methodology followed includes a bibliographic and aerodynamic study of various UAV configurations, followed by aerodynamic and structural analysis of fuselage. The bibliographic study aims to present the capabilities and limitations of each configuration, while the aerodynamic study seeks to justify the selection of the canard layout. Subsequently an aerodynamic analysis of the UAV is conducted using Computational Fluid Dynamics in ANSYS Fluent to deeper understand its behavior under real flight conditions. Finally, a structural analysis of the fuselage is conducted with the aim of understanding the state of stress and ensuring its structural integrity under different loading scenarios. Finally, a buckling analysis of the fuselage structure is conducted to determine the critical load that causes instability.

Emphasis is placed on optimizing the design at both structural and aerodynamic levels. The goal of structural optimization is to minimize the weight of the structure while maintaining its structural integrity and buckling resistance. Meanwhile, the objective of aerodynamic analysis is to reduce drag and improve aerodynamic efficiency.

To ensure the reliability of structural and aerodynamic calculations, a comparison will be conducted with theoretical computational models and numerical solving methods respectively.

Keywords

Unmanned Aerial Vehicle, Preliminary Design, Computational Fluid Dynamics, Finite Element Analysis, Optimization

MODE II INTERLUMINAR FATIQUE TESTS OF CFRP'S MODIFIED WITH BIRMALEIMIDE RESIN

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ABSTRACT

The diploma thesis examines the interlaminar fracture mechanics behaviour of Mode II carbon fibre reinforced polymers (CFRPs) modified with bismaleimide material under fatigue conditions.

The thesis analyses polymeric materials, composite materials, and specifically CFRPs, focusing on their properties, manufacturing methods, and fatigue behaviour. It references graphene nanoparticles (GNPs) and bismaleimide (BMI) resin as modifying materials.

Self-healing materials and their mechanisms are presented, as well as the melt electrowriting (MEW) technique. Fracture forms and types are analysed, with emphasis on Mode II fracture.

The experimental part includes the preparation of CFRP specimens modified with BMI and GNPs, which are subjected to Mode II fracture experiments. The test results are presented, including load-displacement curves, compliance, and energy release rate.

Finally, the recovery of specimen properties through the self-healing process is examined, with calculation of the healing efficiency.

Keywords

self-healing materials, composite materials (CFRPs), melt electrospinning, graphene nanoplatelets (GNPs), Mode II fracture.

STUDY AND ANALYSIS OF ACOUSTIC GUITAR MADE OF COMPOSITE MATERIALS

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ABSTRACT

The present thesis examines the impacts of deforestation and the lack of high-quality wood on guitar construction, exploring alternative solutions through composite materials. Initially, an introduction to acoustic guitars is provided, discussing their origins and anatomy. Subsequently, a literature review is conducted on the materials used in the acoustic guitar industry. Following this, reference is made to the types of analysis that will be applied in this study to investigate and compare the properties of guitars made from wood, composite materials, and hybrid designs. These analysis types are two: modal analysis and harmonic response analysis using Ansys Workbench software. Moving forward, this thesis presents in detail the methodology followed to carry out the aforementioned analyses. It begins with the presentation of the geometry used, the material assignments for the different types of guitars, the connections between their components, and continues with the definition of the boundary conditions applied in each type of analysis. The results of each analysis are then presented, along with their interpretation, to determine which type of acoustic guitar is more suitable for each potential condition. Finally, the conclusions drawn from both types of analysis are presented for the three most prevalent types of guitars: wooden, hybrid, and a type with a body made of composite materials. This thesis concludes with proposals for future extensions that arise from the writing of this work.

Keywords

Guitar, Carbon Fiber, Wood, Natural Frequencies, Mode Shapes

DAMAGE DETECTION IN PIEZOELECTRIC ACTIVE SENSORY SUBJECTED UNDER CRYOGENIC TEMPERATURES

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ABSTRACT

The aviation industry in its search for greener forms of energy has shown particular interest in the use of hydrogen. But hydrogen presents great difficulties in storage. The structures used for this purpose require frequent testing for safety reasons. This thesis examines fault diagnosis systems to meet this need. It deals with systems that are to be exposed to cryogenic temperatures in particular. The thesis sets two main objectives. First, a literature review is conducted on the methods in which fault diagnosis is achieved, with emphasis given on systems that make use of piezoelectric elements (PWAS). Next, an experiment is conducted to test piezoelectric ceramics (PZT) for durability at cryogenic temperatures. These temperatures are achieved experimentally using liquid nitrogen. An epoxy resin that is used to bond the PZT with the structure is also tested for durability. Finally, an SHM system capable of surviving cryogenic temperatures has been constructed. That system detects the degradation that appears in CFRP composites due to thermal stress, utilizing the wave propagation.

Keywords

Structural Health Monitoring (SHM), Wave propagation, Piezoelectric Wafer Active Sensory (PWAS), Non-Destructive Testing (NDT), Cryogenic temperatures.

ENVIRONMENTALLY FRIENTLY RECYCLING OF CFRPs

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ABSTRACT

The continuously increasing use of composite materials in recent years has raised the issue of waste management associated with them. In the context of the present Thesis, a novel approach to the chemical recycling of carbon reinforced polymers (CFRPs) is presented. An aqueous solution of hydrogen peroxide is used to dissolve the epoxy resin and reclaim the carbon fiber layers. The ability of two different concentrations of the solution, 35% v/v and 50%, to dissolve the resin is examined. The reaction conditions are set to 90 °C and atmospheric pressure. The reclaimed carbon fabric layers are used in the creation of new CFRP and its mechanical properties are evaluated. The resin decomposition ratio is calculated via weighting, thermogravimetric analysis (TGA) and examination of the recycled carbon fibers with a scanning electron microscope (SEM). The morphology of the new CFRP is compared to that of the pristine material through ultrasonic scanning (C-Scan) and observation with an optical microscope. The reinforcing ability of the recycled layers of carbon fibers is evaluated through the three-point bending of specimens made of the new CFRP that contains them and specimens of the initial CFRP. In addition, the type of failure of the tree-point bending coupons is examined with SEM observation of the fracture cross section. Finally, an estimate of the energy cost for the proposed method, is given. Results show that the solution with the concentration of 50% v/v is superior. 97.4% wt. of the resin is removed and confirmed through the SEM images, while the behavior of the recycled carbon fibers in the three-point bending tests is similar to that of the pristine fibers. The energy cost of this method is estimated at about 55 MJ/kg, lower than the averages reported in bibliography for the various solvolysis methods and there is room for improvement in terms of the equipment used. All the aforementioned are strong evidence that the proposed reagent belongs to the most effective ones.

Keywords

Composite materials, carbon fibers, recycling, solvolysis, hydrogen peroxide.

COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION OF THE COMPRESSIVE RESPONSE OF 3D PRINTED PERIODIC LATTICE SANDWICH STRUCTURES

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ABSTRACT

Additive manufacturing (AM) has made great progress in the last decade and is considered cutting-edge. Another name for additive manufacturing is 3D printing which has revolutionized industrial production due to its ability to create complex geometries with high precision that were previously unattainable using traditional methods. There are many different techniques and materials for producing components that meet various industrial needs. With the rise in 3D printing and computational power, the production of lattice structures has increased significantly, since their manufacturing is only possible through this technology. Even though, lattice structures have a long history in both nature (bones, honeycombs) and mechanical engineering advancements, their commercial use began now. One definition of these structures is that they are 3D frameworks composed of consecutively and repeatedly arranged interconnected cells, or they can be classified as porous materials, made of interconnected struts and nodes in a 3D space. Some reasons for their wide use are their remarkable mechanical properties, they are lightweight and strong at the same time, they can efficiently distribute loads thanks to their geometry, and they can be easily customized for different applications. They have many uses in the biomedical fields, as well as structural and aerospace engineering. In this student thesis, the different categories of lattice structures are presented, and a lattice geometry is designed, and then 3D-printed using Fused Deposition Modeling (FDM) technology. Firstly, tensile tests and a modal analysis are conducted to calculate the mechanical properties of the material used. Subsequently, the lattice geometry and sandwich structures containing it are subjected to various tests, including compression and three-point bending, in order to observe their behavior under these loading conditions. Finally, a computational study is performed, where finite element analysis (FEA) is

used to simulate all experiments, ensuring the validation of the material’s behavior and test results.

Keywords

Additive Manufacturing, 3D printing, Lattice Structures, Compression Tests, Finite Element Analysis

DIVISION OF DESIGN AND MANUFACTURING (FEBRUARY 2025)

TRIBOLOGICAL DESIGN IN HYDRODYNAMIC REGION OF JOURNAL BEARINGS LUBRICATED WITH LUBRICANTS CONTAINING NANOPARTICLES

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ABSTRACT

Bearings are machine components used to prevent and limit the appearance of friction between solid surfaces in relative motion. Their main purpose is to achieve the desired load capacity with as little friction as possible and as little wear as possible. During their operation, the shaft rotates in an eccentric position within the bearing cylinder and the lubricant is in the wedge gap between the shaft and the bearing, forming a fluid dynamic pressure effect. When the pressure is balanced with the external load, a stable oil film is formed allowing hydrodynamic lubrication.

This diploma thesis presents a comprehensive hydrodynamic study of sliding bearings, studying the developing pressures during their operation. The study was carried out for different eccentricity ratios, different L/D ratios and different types of lubricants both standard industrial and lubricants with added nanoparticles. Firstly, the necessary theory is given to clarify basic meanings in the field of lubrication. The geometry of the sliding bearing is defined, and the basic principles of hydrodynamic lubrication are noted. The theory is concluded by presenting an analytical static and thermal solution of sliding bearings.

In the design part, simulation is performed by CFD method in Ansys Fluent for the case of the narrow sliding bearing without groove. The basic geometric characteristics, boundary conditions, lubricant properties are introduced, the finite element mesh is created in the film

and the developed pressure distribution for each case is obtained. The analytical solution of the sliding bearings was compared with published results.

The second part of the diploma thesis presents an experimental procedure carried out to measure the viscosity of lubricants. The experiment was carried out in the Machine Computation and Design Laboratory (MDL) and the device used is the EH105 capillary tube viscometer from DELTALAB. The lubricant to be studied is placed in the container while pressure is applied, flows into the capillary tube at the temperature set and then passes through the calibrated pipette. By measuring the time, it took to fill the pipette, we calculate the viscosity of the lubricant. The results of these measurements are presented for lubricant SAE30, that was also used in the Ansys simulation, as well as evaluated.

Keywords

Hydrodynamic lubrication, Sliding Bearing, Nanoparticle lubricants, Viscometer, Capillary tube

VIBRATION-BASED DYNAMICS IDENTIFICATION AND DAMAGE DETECTION VIA RANDOM COEFFICIENT MODEL-BASED METHODS IN A POPULATION OF STRUCTURES UNDER STOCHASTIC UNCERTAINTY

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ABSTRACT

The subject of the present thesis is the examination of the efficacy of Random Coefficient (RC) model-based methods in the detection of incipient damage, of variable magnitude and position, in a population of nominally identical structures with manufacturing variability. The problem lies in the difficulty of proper modelling of unmeasurable stochastic uncertainties, such as manufacturing uncertainty, and therefore, in distinguishing the effects of uncertainties from those of incipient damage. For addressing this problem, acceleration response signals of a population of 8-DOF systems – healthy and damaged – with variability in their physical parameters are simulated. Then, by using the simulated signals obtained from the healthy population, Random Coefficient Autoregressive (RC-AR) models, estimated via two methods, the Mean Group (MG) method and a Bayesian Inference (BI) framework, and Random Coefficient Autoregressive Moving Average (RC-ARMA) models estimated via the MG method are proposed and evaluated. Firstly, the order of the RC models is selected based on their effectiveness in estimating the healthy population's natural frequencies, which constitute dynamic characteristics of the population. Then, RC models are estimated via a variable number M of baseline signals and applied to the natural frequencies estimation and damage detection problems. The number of baseline signals does not seem to clearly affect the natural frequencies estimates, while for $M \geq 80$ the damage detection results converge. Subsequently, the RC models of the selected order (based on structural dynamics identification) are compared to corresponding RC models of order selected via the BIC criterion in respect to their effectiveness in detecting damage. RC models of order selected via the BIC criterion lead to lower accuracy. Damage scenarios of variable position are also evaluated; damage closer to the output sensor is easier to detect regardless of its effect on the structural dynamics. Lastly, the postulated RC model-based damage detection methods are compared to corresponding Multiple Model (MM) model-based ones. The RC methods lead to slightly better results.

Keywords

structural dynamics identification, vibration-based damage detection, Random Coefficient models, unmeasurable stochastic uncertainty, population-based variability

DESIGN AND DEVELOPMENT OF A HYBRID CELL DIGITAL TWIN FOR PROCESS CONTROL OPTIMIZATION

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ABSTRACT

This diploma thesis addresses the issue of digital twin of a hybrid cell in manufacturing. In the current highly competitive business environment (Mourtzis, 2020) and the increasing demand for personalized products (Mourtzis, 2022a), the necessity of investigating potential system alternatives towards a more efficient manufacturing system design arises more intensely than ever (Mourtzis, 2020). In an era of economic uncertainty and increased awareness for the ecosystem, sustainability is and will be a crucial issue that will influence many aspects in the industry (Garetti & Taisch, 2012). To overcome the challenges of waste, high operating costs, and deviations in production, enterprises have begun to transition their production practices to Industry 4.0, also referred to as the Fourth Industrial Revolution (Mourtzis et al., 2022), that has emerged in the present-day period (Ebni et al., 2023). One of the concepts that Industry 4.0 has brought to surface is the Digital Twin (Pires et al., 2019). The digital twin, as a virtual representation of a physical object or system, can transfer real-time data on the production process (Stavropoulos & Mourtzis, 2022), enabling predictive capabilities to increase productivity, resulting in improved decision-making, risk mitigation, and efficient resource allocation (Soori et al., 2023a). This thesis proposes a novel design for a hybrid cell digital twin focused on optimizing additive manufacturing and milling processes. Hybrid cells provide flexibility, reduced lead times and can create personalized products in smaller batches. The research methodology starts with creating a 3D model to simulate the physical system in software. Subsequently, communication protocols will be employed to interoperate the physical and digital systems to collect and fuse data to be used to optimize production in the hybrid cell.

Keywords

Hybrid Cell, Digital Twin, Optimization, Industry 4.0, Manufacturing

WORKFLOW FOR THE PROCESS KNOWLEDGE GENERATION IN WIRE ARC ADDITIVE MANUFACTURING (WAAM), USING PROCESS DATA AND METROLOGY RESPONSES: CASE STUDY IN CONSTRUCTION SECTOR

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ABSTRACT

The adoption of Directed Energy Deposition (DED) Additive Manufacturing (AM) processes by the industry rises rapidly since they can provide parts with improved mechanical properties due to the unique characteristics of the AM process mechanism. Specifically, the Wire Arc AM (WAAM) gets industrial interest since it can provide large scale, defect-free, high-quality metal components, whose mechanical properties can be directly compared with those of established conventional manufacturing processes. Despite these benefits, the holistic adoption from Small and Medium Enterprises (SMEs) is held back due to the strong dependence of process stability on process variables and process phenomena that affect the melt pool and bead dimensions and consequently the continuity of the deposition process, leading to failed parts. This work aims to address the challenge of identifying workflows to correlate in line process monitoring data with the process and part key performance indicators (KPIs), leveraging also metrology responses. The first step of the enclosed methodology is to capture the key process phenomena by investigating the effect of process variables on bead dimensions during the process window development phase. After that, the generated knowledge is used to develop solid parts where the process phenomena are evolving in a more complex way, depicting the need for process control. Therefore, the last step is to identify control strategies that can be used irrespective of the part geometry so as to enable a stable process during the development of real-life case studies. Finally, the workflow is assessed in a case study from the construction sector, where different deposition strategies are tested so as to improve the part quality by modifying its surface geometry. The metrology results point

out a perfect correlation between the process data and the overall part distortion, paving the way for the development of data-driven models for the in-line prediction of part quality.

Keywords

Additive Manufacturing, Wire Arc Additive Manufacturing (WAAM), Workflow, Construction, Metrology

FAULT DETECTION IN COMPOSITE AIRFRAME UNDER VARYING TEMPERATURE VIA VIBRATION BASED MACHINE LEARNING METHODS

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ABSTRACT

The present study focuses on Structural Health Monitoring (SHM) through vibration signals, aiming at the detection and characterization of damage in aerospace structures. The main issue addressed concerns environmental and operational conditions, specifically temperature, which varies over a wide range (-40℃ to 40℃). For this study, a simulation model based on the Finite Element Method (FEM) is used, implemented in Abaqus under random excitation. Damage is examined as interlaminar delamination, modeled as local material degradation. In total, 12 damage scenarios are studied, resulting from variations in the interlayer thickness, the material degradation factor, and the damage area size. To detect and characterize damage, two approaches based on Principal Component Analysis (PCA) are applied: classical PCA and PCA with regression (PCA-regression), which incorporates the influence of environmental conditions. These methods are applied to both non-parametric models, such as Power Spectral Density (PSD) and Vector Power Spectral Density (V-PSD), and parametric models, such as AutoRegressive (AR) and Vector AutoRegressive (VAR). Damage detection is performed using Mahalanobis distance, while damage characterization is conducted through machine learning classification algorithms, including k-Nearest Neighbors, Decision Tree, Random Forest, Support Vector Machine, and Naïve Bayes. The comparison of methodologies highlighted PCA-VAR as the most efficient approach, achieving perfect damage detection. Regarding damage characterization, PCA-VAR combined with the Naïve Bayes algorithm achieved 71% accuracy, making it the most reliable approach.

Keywords

Vibration based SHM, Composite structures, Thermal uncertainty, Machine Learning Methods, Principal Component Analysis

DAMAGE DETECTION IN COMPOSITE STRUCTURES UNDER UNCERTANTIES VIA RANDOM VIBRATION

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ABSTRACT

Composite materials are increasingly used in various engineering applications, particularly in aerostructures, due to their exceptional mechanical properties and high strength-to-weight ratio. However, their sensitivity to uncertainties caused by varying Environmental and Operating Conditions (EOCs) poses significant challenges for effective damage detection. Vibration-based Structural Health Monitoring (SHM) in composites has become a field of significant interest mainly because vibration is naturally available for most structures. A major issue in vibration-based SHM stems from the fact that variations in the structural dynamics caused by the varying EOCs and other uncertainty factors can be so pronounced that they partially or even completely obscure the dynamic changes associated with early-stage damage. Therefore, distinguishing the effects of EOCs and uncertainties from those induced by damage is crucial for effective vibration-based SHM. In the present study, the problem of random vibration-based robust damage detection for a composite aerostructure under temperature, manufacturing uncertainty and a distributed excitation profile is numerically addressed. A three-dimensional, four-node shell element of linear order with six degrees of freedom per node is employed for the Finite Element Method (FEM). Temperature varies within the [−40, 20]°C range and is modelled to affect the material properties and damping ratio of the structure. Manufacturing uncertainty is modelled as a variation in the material properties involving the vertical and transverse directions. Additionally, a distributed excitation profile that simulates the real in-flight conditions, based on the Dryden turbulence model, is considered. Delamination is implemented by stiffness degradation in the middle layers of the structure and is considered at three distinct locations: (i) near the boundary condition, (ii) near the middle, and (iii) near the tip of the structure. Three methods, all utilizing acceleration-response signals and based on Multiple Input Multiple Output (MIMO) Transmittance Function (TF) representations of the structural dynamics estimated via stochastic Vector AutoRegressive with eXogenous excitation (VARX) models, are employed for damage detection: (i) an U-PCA-VARX method, and two Multiple Model (MM)-based methods: (ii) an U-MM-VARX method, and (iii) a PCA-enhanced, U-PCA-MM-VARX, method. The study is extensive, based on hundreds of Monte Carlo simulations conducted across a wide range of temperatures. The inspection phase of the damage detection process is structured into two distinct sub-phases: one within the [0, 20]°C temperature range, corresponding to inspections conducted under controlled laboratory conditions, and the other within the [−40, 0]°C range, representing experiments conducted under a real operating regime. All methods achieve excellent damage detection results for both inspection phases considered.

Keywords

Vibration-based Structural Health Monitoring, Robust damage detection, Uncertainty, Multiple Model method, Principal Component Analysis

FORCE EXCITATION RECONSTRUCTION IN A CANTILEVER BEAM USING INVERSE ARX (IARX) MODELS AND REGULARIZATION METHODS

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ABSTRACT

The present thesis aims at the accurate reconstruction of unknown excitation forces applied to a metallic cantilever beam, using only vibration acceleration signals and a data-driven parametric model. The model is identified based on a single pair of a white noise excitation signal and its corresponding response signal. Knowledge of the force excitations applied on structures is highly beneficial for vibration analysis. It is crucial for numerous applications like vibration prediction and control, damage detection and fatigue life estimation. However, measuring the dynamic inputs acting on a structure is often impractical, challenging, or even impossible. In most cases the only available measurements are the ones of the response signal. In such instances, estimating the input signal becomes the only viable solution to gain insights on the dynamics of the force excitation. This problem belongs to the category of inverse problems, that is, those that involve determining the causes of a phenomenon from the observations of its outcome. The present thesis utilizes a novel data-driven Inverse ARX method for the accurate solving of such a problem, namely the efficient reconstruction of force excitation signals applied on a metallic cantilever beam, using only acceleration response measurements and a single white noise type excitation signal. Three sensors are used to collect vibration acceleration data which serve as inputs to the IARX model that corresponds to each sensor. Initially, this study explores force reconstruction via Inversion of the Parametric Transfer Function of ARX models, supported by Regularization techniques such as ℓ_2-regularization and ℓ_1-regularization. Nevertheless, as the research progresses it becomes evident that the Regularization techniques are insufficient for the inversion of non-minimum phase models. This constitutes the primary limitation of the investigated method, and it means that when non-minimum phase zeros exist, the inverse problem is ill-posed and thus unsolvable. At this point the IARX method emerges as a superior alternative. This methodology was previously introduced as a technique for boundary specification in heat conduction problems, specifically for estimating the input heat flux on a boundary, based on measured temperature data. In this thesis the IARX model is employed to estimate force signals, while the measured acceleration responses serve as the input of the model. A distinguishing feature of the method is the fact that future eXogenous inputs are also used for the estimation of the output signal. For each sensor, an optimal IARX model is estimated based on classic system identification criteria using a measured GWN input force signal. The selected models successfully reconstruct colored noise signals, sinusoidal signals and impact forces for all sensors. Furthermore, during the testing of the estimated IARX models, the reconstructed excitation signals exhibit a high degree of alignment with the measured signals in both time and frequency domain. Specifically, the time domain reconstruction accuracy is evaluated using two quality indicators: the normalized coefficient of determination $R^2{}_{norm}$ and the Time Response Assurance Criterion ($TRAC$). In the frequency domain, the accuracy is assessed using the Frequency Response Assurance Criterion ($FRAC$). The values of the criteria range from zero to one, the value of one corresponding to perfect correlation between them-meaning perfect force reconstruction, and zero indicating no correlation between them, signifying poor reconstruction accuracy. The IARX methodology demonstrates strong performance, with all criterion values exceeding 0.9 in most cases.

Keywords

parametric model inversion, regularization methods, IARX model, future exogenous parameters, well-posed problem

DESIGN, SIMULATION, AND DEVELOPMENT OF COLLABORATIVE ROBOTIC ARMS WITH 5 DEGREES OF FREEDOM FEATURING LINEAR DISPLACEMENTS AND THEIR INTERGRATION INTO A MOBILE ROBOTIC PLATFORM FOR PLANETARY EXPLORATION

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ABSTRACT

The content of this diploma thesis covers the design, simulation and development of a Robotic Arm with 5-degress of freedom with linear displacement on its base focusing on the mechanical aspect of the robots. In addition, it analyzes the integration of the two collaborative robotic arms into a Mobile Robotic Platform (Rover Sawppy) for planetary exploration. The design and the creation process of the robotic platform used (Sawppy Rover) is covered on a previous thesis. The process of designing a robotic arm requires expert knowledge of various mechanical concepts such as link and joint design, kinematics and dynamics, material selection and actuation and power transmission, even more so when the robotic is set to function on planetary exploration missions where different, harsher environmental conditions apply.

The project commenced with the necessary literature research to firstly identify the conditions that apply on different planets and on Mars as it is the planet with the most missions for exploration. Through literature research we encountered the designs of robotic arms that are already in operation in Space, in the ISS or Mars. Of course, the research did not only focus on robotic arms used in space but rather on the everyday life of people around us such as the arms in various hospitals or even human care. The first concept was the creation of a robotic arm with the ability to even have passive joints but quickly the project steered away from such a difficult design. After literature research the phase of development commenced.

In this stage of development various prototypes were created and tested to ensure the design was able to function effectively. The main factor to determine whether a design would function was whether the inverse kinematic problem would have a solution with the current architecture of the robotic arm. After finalizing the design of the robotic arm, the phase of simulation was next using Gazebo and then the creation of a prototype using 3D-Printing and actuators. The completion of the project required also to determine the solution for the linear motion of the robotic arm. Throughout the process, the researcher's expertise in various aspects of mechanical engineering was thoroughly evaluated. This included material selection to ensure durability and performance, bearing selection for optimal rotational movement, and actuation selection to achieve precise and efficient motion control. Additionally, the design required careful consideration of weight distribution to maintain structural stability and functionality. Proficiency in simulation and analysis software was also critical, allowing for the validation of design concepts and performance predictions in a virtual environment.

The electronic integration of the system is based on an ESP32, which enables the management of the servo motors through serial communication, reducing wiring complexity. The system is also equipped with temperature and voltage sensors, which activate cooling fans and halt operation if safe limits are exceeded.

The software development includes the implementation of an inverse kinematics model, which was developed using MoveIt2 and a custom kinematics algorithm in Python. The system is fully integrated with ROS 2, RViz, and Gazebo, allowing for real-time simulation and testing before executing actual movements.

Experimental testing demonstrated that the robotic arm can perform complex motions, handle a payload of 500g, and operate efficiently when powered at 12V and 2.5A. In the future, the objective is to optimize the design using generative design techniques, integrate perception sensors, and enhance autonomy through real-time connectivity with ROS 2.

Keywords

Robotic Manipulation, Planetary Exploration, Inverse Kinematics, Mobile Robotics, Robotic Arm Mechanical Design

DEVELOPMENT OF A SUSTAINABILITY-DRIVEN DESIGN APPROACH FOR AIRCRAFT COMPOSITE COMPONENTS

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ABSTRACT

In order to tackle the global environmental crisis that is on rise, there is a worldwide trend to shift traditional product design processes into novel ones that integrate sustainability concerns. A strategy is proposed in this study that introduces sustainability practices from the conceptual design phase, broadening the scope beyond environmental considerations that are mainly accounted in existing design strategies nowadays. This approach's scope includes not only mechanical performance goals linked to safety regulations, and environmental impact evaluations but also aspects including costs, social implications, and circular potential. To illustrate this strategy, a common component from the aviation industry, in particular a hat stiffened panel, is considered. Multiple material configurations are evaluated, although the emphasis is given to composite materials, since they are greatly promising for current and future applications in the aviation sector. Moreover, geometrical modifications are investigated to obtain the optimal design with regard to all the sustainability criteria considered. In order to produce the most sustainable design that successfully achieves a compromise between structural and sustainability criteria, these aspects are methodically measured and adjusted throughout the design process.

Keywords

design for sustainability, sustainability-driven design, aircraft design, eco-design, hat stiffened panel

IMPLEMENTATION OF OVER DEPOSITION CONTROL STRATEGIES FOR WIRE DIRECTED ENERGY DEPOSITION (DED) ADDITIVE MANUFACTURING (AM) PROCESSES OPTIMIZATION

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ABSTRACT

The increasing industrial competition and the customer demands for extended product lifecycle via remanufacturing workflows, has paved the way for the cost- and resource-efficient wire laser-based Directed Energy Deposition (DED-LB) process. Despite its advantageous features linked with the provision of high density, defect-free parts, wire DED-LB is a non-mature process, governed by complex process phenomena which need to be controlled based on feedback from process monitoring devices. However, these solutions are not market-available, limiting the interest of industrial world. These tools are essential for enabling unsupervised part development and tracking process history for future reference. Therefore, this work presents the workflow for the creation of a control methodology which aims to achieve process stability by leveraging the data from an embedded on the deposition head load cell to evaluate the distance between the deposition head and the working surface (Standoff distance- SoD). To achieve that, the effect of the process phenomena that cause SoD variations – heat accumulation and part geometry – on the load cell signal are investigated. By examining the acquired signal from various geometries and process parameter combinations, robust statistical metrics are extracted that describe both the whole layer as well as subsets of it, and the key load cell signal features are determined. To leverage this information towards the SoD control strategy development, a multilevel experimental investigation is designed. The first phase involves the development of a relationship between the load cell signal and the variations from the optimal SoD in order to provide real-time feedback to the machine operator. The second phase focuses on the corrective actions to be applied when the investigates the process parameter with the most direct influence on SoD. The final phase is designed to unfold an extra functionality of the present monitoring system, that of the expansion of the operational process window, by utilizing it for the initial layer height selection for two never-before-studied sets of parameters. By correlating process monitoring data with metrology data, this approach generates valuable insights that drive corrective actions and optimize the process.

Keywords

Additive Manufacturing, laser-based Directed Energy Deposition DED-LB, coaxial wire, load cell, Standoff distance (SoD), Control strategies

ROBUST DIAGNOSIS OF INCIPIENT SURFACE GEAR WEAR IN A SINGLE-STAGE GEARBOX UNDER VARYING OPERATING SPEED AND LOAD USING ADVANCED VIBRATION-BASED STATISTICAL TIME-SERIES METHODS

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ABSTRACT

This study investigates the capability of automated detection of incipient surface gear wear in a single-stage spur gearbox under varying speed and load conditions, based on vibration signals and advanced statistical time series methods. The problem is particularly challenging because faults do not cause obvious effects in the time-domain signals or their statistical characteristics (RMS, peak value, kurtosis, crest factor). This specific problem has not been thoroughly studied in the literature, as there are limited studies on simultaneously varying speed and load, combined with a wide range of experimental data. To address this issue, the Multiple Model (MM) approach is utilized. The objective of this method is to represent the dynamic behavior of the gearbox in the healthy condition using multiple models. Different features are employed in the method, including autoregressive models (AR), order spectrum, Time Synchronous Averaging (TSA), TSA spectrum and squared envelope TSA. The experimental setup consists of a single-stage gearbox with bearings, two shafts, and a pair of meshing gears: a pinion with 17 teeth and a gear with 34 teeth, leading to a 2:1 transmission ratio. The gearbox is driven by an AC electric motor and loaded by a DC motor operating as generator, while two triaxial accelerometers collect data from the bearings of both input and output shafts. The vibration signals used in this study originate from the output shaft in the vertical direction relative to the mounting and perpendicular to the shaft. The performance of the methods is evaluated through thousands of experiments conducted across 81 different speeds, ranging from 5 to 25 Hz, in increments of 0.25 Hz, and four different load conditions. In the first case, the gearbox is unloaded, in the second case, it is loaded with the inertia of a permanent magnet generator, in the third case, the generator is connected to a 500W electrical load, while in the fourth case, it is connected to two electrical loads totaling 1kW. Fault scenarios are categorized into four levels based on the percentage of artificial surface gear wear propagating at the base of one of the 17 pinion teeth: 25%, 50%, 75%, and 100%. The total number of experimental measurements is 8100, as five individual experimental measurements are collected for each combination of health condition, speed, and load. The MM-AR achieves outstanding fault detection performance under simultaneously varying speed and load conditions. In MM versions of the method under unknown load but known speed during the inspection phase, performance is assessed through the Local AUC metric. The MM-AR achieves a Local AUC score of 99%, the MM-AR order scores 98.6%, the MM-Order Spectrum scores 76.3%, and the MM-TSA Spectrum scores 80.3%. However, the MM-TSA and MM-Squared Envelope TSA are deemed unsuitable, with Local AUC scores of 11.7% and 16%, respectively.

Keywords

Single-state spur gearbox, detection of incipient surface gear wear, varying operating conditions, vibration-based statistical time series methods

TRIBOLOGICAL DESIGN OF KNEE JOINT IN MIXED LUBRICATION OPERATIONAL REGIME

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ABSTRACT

In this paper, the tribological design of an artificial knee joint under mixed lubrication regime is carried out using the finite element analysis (FEA) software ANSYS. The debate on artificial joints has been going on since the beginning of the 20th century and many computational and experimental studies have been carried out over the years. The aim of these has been to optimize their lifetime. Artificial joints find application in cases of people whose natural joint has failed, resulting in an inability to move it or severe pain when moving it. The reason for the failure of each joint (friction between the parts of the joint due to lack of lubricant) makes it necessary to study further the artificial joints and the operating cycle of the natural joint, with a view to the correct replacement of the latter. Initially, general elements of the knee joint were studied, such as the bones involved, the gait cycle, its lubrication and the bio-lubricants that can be used. Then, tools such as the Reynolds equation for hydrodynamic lubrication and the Greenwood and Tripp model were used to understand the roughness of the model, in areas where there is contact between lubricating surfaces, since a mixed lubrication regime exists. The MATLAB programming model was used for the computational process, for the Reynolds model validation, while the ANSYS package with the Discovery application was used for the design and analysis. Thus, analytical diagrams are given for the loading of the model, stress distribution and the robustness of the model and the materials selected during design.

Keywords

Biotribology, artificial joints, friction, mixed lubrication

VIBRATION-BASED IMBALANCE DETECTION IN A POPULATION OF OFFSHORE WIND TURBINES UNDER VARYING ENVIRONMENTAL CONDITIONS VIA NEURAL NETWORKS AND STATISTICAL TIME SERIES BASED METHODS

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ABSTRACT

The increasing global demand for renewable energy has driven a rise in offshore wind turbine installations due to their higher energy yields and reduced maintenance needs compared to onshore turbines. However, offshore turbines are vulnerable to various forms of damage, including rotor imbalances, which can induce excessive vibrations, mechanical stress, and costly downtime. Early detection through Structural Health Monitoring (SHM) is crucial to mitigating these issues. This research formulates an unsupervised methodology for detecting both mass and aerodynamic rotor imbalances in an offshore wind turbine population within the same farm. The approach relies on vibrational data from nacelle-mounted accelerometers, collected over a year during normal operation when the turbine produces rated power. To enhance robustness, the methodology accounts for uncertainty factors introduced by varying environmental conditions and structural inconsistencies across turbines, ensuring a more reliable and scalable detection framework. The detection framework integrates Artificial Neural Networks (ANN) and Statistical Time Series (STS) methods. An Autoencoder (AE) is employed for ANN-based detection, while the Multiple Model (MM) concept is applied for STS-based methods. System dynamics are represented through both parametric and non-parametric techniques, including Welch-based Power Spectral Density (PSD), Cross Power Spectral Density (CSD), and parametric models such as Autoregressive (AR) and Vector Autoregressive (VAR). Vibration signals are analyzed in three directions—side-to-side, fore-aft, and longitudinal—and two of the healthy turbines are used to train the models, establishing a reference standard for unsupervised detection capable of distinguishing between healthy and faulty turbines. The results demonstrate that the detection methods generally provide reliable performance. Both non-parametric (PSD and CSD) and parametric (AR) modeling effectively represent system dynamics for imbalance detection, except for VAR modeling. MM-based methods achieve the highest overall detection rates for both types of imbalances; however, AE-PSD outperforms all other approaches in mass imbalance detection. The fore-aft and longitudinal signals are more effective for detecting aerodynamic imbalance, while the side-to-side signals are better for mass imbalance, aligning with the distinct vibration patterns of each imbalance type. These findings highlight the effectiveness and scalability of the proposed methodology for detecting rotor imbalances across multiple turbines within a wind farm under varying environmental conditions.

Keywords

Offshore Wind Turbine Population, Rotor Imbalance Detection, Neural Network, Statistical Time Series Method, Nacelle accelerations, Varying Environmental Conditions

DEVELOPMENT OF A METHOD FOR DESIGN AND EVALUATION OF INDUSTRIAL CELLS BASED ON HUMAN ROBOT COLLABORATION

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ABSTRACT

In recent years, market demands have emphasized the need for greater product variety, personalization of products and shorter lifecycles. To deal with these requirements, manufacturing systems need to become highly flexible and demonstrate reasoning, dexterity and adaptation capabilities. In this direction, hybrid industrial cells, based on human robot collaboration, could enhance manufacturing systems by combining human's dexterity and problem-solving abilities with robot's tireless repeatability and precision. Nevertheless, despite its advantages, implementing hybrid systems introduces challenges such as high implementation costs, safety risks, and expertise requirements. These challenges can be mitigated and constrained during the system engineering phases through proper design decisions. Therefore, this diploma thesis aims on developing a method for the design and evaluation of industrial cells implementing HRC. This method defines the core parameters that shape an HRC system and provides engineers with a structured, step-by-step approach to their effective integration, ensuring both production efficiency and workplace safety. Additionally, an evaluation worksheet is presented that can assist the engineer in assessing an HRC workspace, compare it against its optimal scenario, and identify inefficiencies and opportunities for improvement. The applicability of the method is validated through three different industrial scenarios. Each case study compares the "ideal" system specifications with the actual implementation, highlighting both its attributes and areas for refinement. On business level, this method can support enterprises by reducing ramp up periods, implementation costs, and managing the enabling technology deployment based on the available workforce skills.

Keywords

Human-Robot Collaboration, Collaborative Workspace, Human-Robot Interaction, Evaluation Methodology, Key Parameters

TRIBOLOGICAL DESIGN OF HYDROGEN FUEL INTERNAL COMBUSTION ENGINES. THE INFLUENCE OF ELASTICITY AND SURFACE TREATMENT

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ABSTRACT

Hydrogen may emerge as the fuel of the future due to its combustion properties. Its use, as opposed to conventional fuels in applications such as internal combustion engines (ICE), will contribute to reducing carbon emissions and other greenhouse gases. Moreover, in the context of current geopolitical developments, hydrogen can serve as a key factor in decoupling human energy needs from finite fossil fuels. Therefore, the present diploma thesis examines the potential for utilizing hydrogen as a fuel in ICE by comparing it with gasoline (C8H18).

Specifically, the study involves modeling the phenomenon of gas leakage (Blow-by) from the combustion chamber into the crankcase, focusing on the first compression ring of a four-stroke reciprocating engine. This phenomenon directly affects the engine's performance, lubricant and fuel consumption, and ultimately pollutant emissions.

The objective of this modeling is to determine the pressure of the gases momentarily trapped behind the first compression ring as a function of the crank angle. This pressure used as an input value for a suitable CFD code, which allows the calculation of the minimum lubricant film thickness, through computational fluid dynamics analysis, as well as the friction developing between the tribological pair, compression ring / cylinder walls. To achieve even more realistic results, a combined thermal model was used to calculate the potential viscosity of the fuel-air mixture, based on the prevailing temperatures within the cylinder.

The friction between the tribological pair leads to power losses and, consequently, increased fuel consumption in order for the engine to meet the corresponding operating conditions. Therefore, considering that these losses are estimated to be up to 5% of the total losses in ICE and that one third of the consumed fuel is used to compensating the friction, it is deemed

necessary to develop this specific tribological model, compare the results with those for gasoline-powered ICE, and finally draw useful conclusions.

Keywords

ICE, Hydrogen, Gasoline, Blow-by, Dynamic viscosity of fuel-air mixture, Compression ring – liner conjunction, Lubrication

Division of Energy, Aeronautics and Environment (February 2025)

COMPUTATIONAL INVESTIGATION OF SECONDARY FLOW IN LINEAR TURBINE CASCADE

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ABSTRACT

The understanding of secondary flow behaviour has become an important and much needed aspect in the design of modern gas turbines. Secondary flow gives rise to aerodynamic losses, distorts the thermal field and negatively affects the flow conditions at the exit of a blade passage. Numerical investigations of the complex flow field in simple linear turbine cascades have been conducted for decades in order to clarify the flow picture. In this framework, both RANS and LES investigations for the widely used T106 cascade under simulated conditions for a real engine (M_1=0.35, $M_{2,is}$=0.59, $R_{e2,is}$=120k) were selected as a reference point.

Based on these, in the present study, a CFD investigation of an equivalent configuration has been performed in the commercial numerical solver ANSYS Fluent. The formation of vortex structures such as the passage vortex, and quantities such as the pressure coefficient, the turbulent kinetic energy and velocity field have been evaluated and compared to experimental results. Due to limitations in the computational capabilities the quantitative agreement of the results was compromised. However, qualitatively there was good agreement.

Keywords

linear turbine cascade, secondary flows, three-dimensional flow, passage vortex, horseshoe vortex, computational fluid dynamics

EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER IN DOUBLE-PIPE HEAT EXCHANGER WITH INTERNAL GROOVES

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ABSTRACT

Heat exchangers are devices widely used for heat transfer between fluids and are essential components in many industrial and energy applications. Continuous research focuses on improving their performance by maximizing thermal exchange, reducing operational costs, and increasing energy efficiency. This thesis aims to experimentally investigate the effect of internal grooves on the performance of a counterflow double-pipe heat exchanger.

For this purpose, an experimental setup was designed and constructed, consisting of a closed-loop forced flow system with controlled temperatures. This system is supplied with hot water and allows for the comparison of the thermal performance of smooth tubes versus tubes with internal grooves. The study first presents the theoretical background of heat exchangers and methods for enhancing thermal performance, followed by an experimental analysis of the constructed setup.

The experimental study includes measurements of temperature differences at the tube inlets and outlets, pressure drop measurements, and mass flow rate recordings under different flow conditions. The tests were conducted within a Reynolds number range of 9,800 - 29,800, with flow rates between 0.034 - 0.1 kg/s and hot fluid inlet temperatures between 58°C and 63°C. Empirical correlations from the literature were used to analyze the results, with different equations applied to smooth and enhanced tubes.

The findings showed that grooved tubes exhibited a 38%-60% increase in the Nusselt number, confirming the improvement in heat transfer. However, a 26%-40% increase in the friction factor was also observed, indicating higher energy losses due to increased flow resistance.

Finally, recommendations are made for optimizing the geometric characteristics of the grooves, as well as for improving the design of the experimental setup to minimize pressure losses and achieve higher energy efficiency.

Keywords

Heat Transfer, Double-Pipe Heat Exchangers, Internal Grooves, Nusselt Number, Friction Factor

ELECTRIC POWER GENERATION FROM HYDROELECTRIC POWER PLANT - CASE STUDY LADONAS RIVER

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ABSTRACT

In this thesis, reference is made, as its title itself indicates, to two interrelated parts; to the production of electricity from the construction of a hydroelectric project and finally to the use of these techniques in the case of applying these techniques to the exploitation of the waters of the Ladonas River, for the production of power. In the first chapter, reference is made to the elements of which hydroelectric power plants are composed, the start of studies, the construction of a dam and the parts of which it is composed, other connecting elements such as a fall and intake pipe, as well as elements that concern a more mechanical subject, namely types of hydro turbines and how we choose the appropriate one depending on the case we want to install. Subsequently, in the second chapter, a presentation is made of the Hydroelectric Project that already exists on the Ladonas River, a project of key importance for the first post-war years when our country was gradually beginning to be electrified to a greater extent, and finally in the third and final chapter, a study is made of a Small Hydroelectric Plant using the Ladonas River basin in a simulation in a computational environment, suitable for such study cases.

Keywords

Hydroelectric Project, Ladonas river, Computational environment, Electricity, Case study

ANALYSIS OF GREEK SOLAR THERMAL SYSTEMS FOR DOMESTIC USE

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ABSTRACT

Energy is a fundamental necessity for life and human activities. The increasing need for energy efficiency and the use of renewable energy sources has become a priority in the European Union's energy policy. Solar energy, due to its availability and potential, plays a significant role, especially in regions like Greece, where climatic conditions are favorable for its utilization. The present study focuses on the analysis of Greek thermal solar systems for residential use. A market survey was conducted to gather price data from the Greek market, and through a Life Cycle Assessment (LCA), the payback period and CO_2 emissions associated with their production were calculated. Finally, the total amount of emissions saved over their expected lifetime was estimated.

Keywords

Solar thermal systems, Life Cycle Assessment (LCA), Investment payback period, Carbon footprint reduction, Sustainable energy solutions

COMPUTATIONAL SIMULATION OF AIR CONDITIONING FLOW FIELD FROM CEILING AND DORS GRILLES OF SUPPLY OR EXTRACTION OF AIR WITH FIXED OR MANUALLY ADJUSTED VANES FOR 1 TO 4 FLOW DIRECTIONS

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ABSTRACT

This thesis examines the airflow through diffusers in a predefined space, aiming to analyze and evaluate the main characteristics of the flow. The key parameters analyzed include exit velocity, throw, rise, drop, spread, and pressure drop. The pressure drop was calculated through numerical simulations, while the other characteristics were examined computationally using ANSYS Fluent software and experimentally. To investigate the airflow characteristics, analyses and simulations were conducted for four types of diffusers (G1 400x200, DO 600x300, A4 152x152, and A4 457x457). Experimental measurements were carried out in a specially designed space within a room measuring 10 x 5.5 x 2.75 m at the Fluid Mechanics Laboratory of the University of Patras.

The structure of the thesis includes an introduction that outlines the study's purpose and provides a brief historical overview of air conditioning development. The second chapter develops the theoretical background, focusing on ventilation and air conditioning principles. The third chapter describes the experimental methodology, including installation and measurement procedures. The fourth chapter presents the principles of Computational Fluid Dynamics (CFD), including solution algorithms and turbulence models. The fifth chapter analyzes the problem's methodology, while the sixth chapter presents and evaluates the results of simulations and experimental measurements. Finally, the seventh chapter compares computational and experimental results, drawing conclusions about the optimal use of diffusers in ventilation and air conditioning applications. Overall, this thesis contributes to understanding airflow behavior through various diffusers and evaluating the accuracy of

computational simulations compared to experimental data, providing valuable insights for optimizing ventilation systems.

Keywords

Grilles, air flow, computational fluid dynamics, characteristic sizes, experimental measurements

EXPERIMENTAL INVESTIGATION OF THE BEHAVIOUR OF FIRE RESISTANT, INGUMESCENT PAINTS UNDER FIRE

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ABSTRACT

This thesis focuses on the initial experimental investigation of the behavior of fire-resistant intumescent coatings under fire conditions. Fire-resistant coatings are composite materials that use a combination of physicochemical mechanisms to protect the structural materials from fire, as part of the fire protection regulations for buildings and facilities. The main mechanisms include the formation of protective expanded layers that reduce the presence of oxygen around the flame. According to the insulation criteria, the temperature on the unexposed side of the structural element must not exceed an average of 140°C, or a maximum of 180°C at any point during fire exposure. For this reason, structural materials such as steel, aluminum, and wood must be protected from fire to prevent the loss or reduction of their structural properties. Initially, a new experimental setup for small-scale tests was designed, which included a configuration of nine sources of infrared radiation. The intumescent coating used for this thesis was from the company STANCOLAC and was provided as a sample. Steel specimens measuring 10cm x 10cm were coated with various thicknesses of the intumescent coating (750μm, 1200μm, 1600μm), while the thermal flux was maintained constant throughout the experiments (~20kW/m²). The necessary measuring instruments (thermocouples, thermal camera, optical camera, thermal flux measurement sensors) were placed appropriately at specific locations on the specimen and within the experimental setup. The measuring devices were then appropriately connected to a computer for recording, processing, and evaluating the experimental data to measure the temperature on both the exposed and unexposed surfaces of the specimen. Repeated measurements were conducted on the different coating thicknesses to examine the phenomenon and study the behavior of the coated specimen. The temperatures measured at the back side of the specimen agree with the criterion that they should not exceed in average 140° C, and 180°C in maximum values.

Keywords

Intumescent paint, fire resistant, coatings, metallic buildings, steel specimen

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING LINEAR GRILLES WITH INDEPENDENT MANUAL OPERATED GUIDE VANES TO REGULATE THE FLOW TO 2 UP TO 4 DIRECTIONS

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ABSTRACT

The present thesis aims to study and analyze the airflow through vents in a room of specific geometry in order to determine flow-related characteristic quantities. The analysis and determination of these quantities (exit velocity, throw, rise, drop, spread, noise level) are carried out using the Ansys Fluent software, while for the pressure drop, a computational equation is used. Subsequently, the computational and experimental values obtained in the laboratory space of the Fluid Mechanics Laboratory of the University of Patras are compared. The quantities of the parameters were determined for the four different grilles (G1s 400x200, G1s 600x300, G2 400x200, and G2 600x300). The reasoning process of the research and the steps followed are divided into corresponding chapters. In the first chapter, introductory elements are presented, the purpose of the study is analyzed, and a brief historical overview of air conditioning is provided. In the second chapter, various theoretical aspects of ventilation and air conditioning are mentioned. Furthermore, the categories of grilles are classified, and information on thermal comfort is provided. The third chapter covers information about the experimental study, such as the dimensions of the space, the characteristics of the measuring instruments, and the procedures followed. The next chapter introduces computational fluid dynamics and continues with the presentation of corresponding equations and turbulence models. In the fifth chapter, the problem to be solved is designed, including the creation of the room's grid and the determination of the ideal solving conditions in the computational software Ansys Fluent. After calculating the velocities at each grille, the computed results are presented in the sixth chapter. Through flow visualization images, the airflow behavior for each grille is displayed according to the applied airflow rate, and grilles of the same category are compared using common diagrams. The comparison continues with the juxtaposition of

the computational and experimental values to determine the errors of the measured quantities. Finally, in the seventh chapter, the conclusions derived from the analysis of the results are discussed.

Keywords

Airflow, simulation, Characteristic quantities, Ventilation grilles, Computational Fluid Dynamics (CFD)

COMPUTATIONAL SIMULATION OF AIR CONDITIONING FLOW FIELD FROM SWIRLING CEILING GRILLES OF SQUARE FRAME AND VANES IN RADIAL ARRANGEMENT OF SQUARE OR CIRCULAR CONFIGURATION FOR DIFFERENT TEMPERATURES

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ABSTRACT

In this thesis, the airflow from ceiling swirl diffusers in a room of specific dimensions was studied. Initially, basic concepts regarding ventilation and air conditioning of spaces were presented, focusing on forced airflow through ceiling outlets. Emphasis was placed on how these outlets affect the airflow distribution and comfort conditions within the room. Subsequently, the methods of computational fluid dynamics (CFD) that were applied were discussed, including the turbulence models and discretization methods used for airflow simulation. The process of creating the model geometry and selecting the appropriate mesh in the ANSYS Fluent software was also presented, as well as the implementation of boundary conditions, material parameters, and equation-solving methods. The results for different airflows and temperatures were analyzed, and their impact on comfort conditions within the room was evaluated. The study's findings highlighted the areas within the room that provide comfortable conditions and underscored the importance of avoiding high airflows, as they can cause uneven distribution of air velocity, negatively affecting the users' sense of comfort in the space.

Keywords

Air grille, Air distribution, Air supply, Computational Fluid Dynamics (CFD), Air quality, ceiling swirl diffuser

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING VENTS WITH GRILLES OF SLOT TYPE WITHOUT FRAME AND VENTS OF JET TYPE WITH MANUAL REGULATED PLASTIC NOZZLES

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ABSTRACT

This thesis deals with the study of air flow in a room of predetermined dimensions from slotted and jet-type grilles. The aim is to analyze and evaluate the flow characteristics such as rise, drop, spread, velocity distribution and pressure drop. The grilles were designed in SOLIDWORKS, while the calculation and visualization, through diagrams, of the characteristic quantities were performed in ANSYS FLUENT for the cases of zero temperature difference between the incoming and pre-existing air in the room, as well as for temperature difference $\Delta T = +5K$ and $\Delta T = -5K$. In the calculations, the maximum air exit velocity from the outlets is $V_c = 10$ m/s and we defined the region of interest as the one where comfort conditions for a human being prevail, that is up to the point where the air velocity is 0.5 m/s.

Keywords

Nozzle, air flow, characteristic sizes, computational fluid dynamics

APPLICATION OF PHOTOVOLTAIC PLANT AND BATTERY EVERY STORAGE SYSTEMS IN INDUSTRIAL INSTALLATION

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ABSTRACT

This thesis aims to study the integration of an energy storage system into an industrial renewable energy unit, specifically a photovoltaic system. Photovoltaic systems often generate surplus electricity or fail to meet demand, as energy production is unpredictable and dependent on external factors. Therefore, the use of energy storage stations (ESS) is deemed necessary, allowing the electricity grid to "balance" supply and demand from renewable energy production systems. By contributing to this balance, energy storage stations significantly improve the efficiency of renewable energy sources and enable maximum penetration of renewable energy into the national energy mix. Furthermore, this study extends to the application of a combined photovoltaic and energy storage system in an industrial facility that meets its energy needs through self-consumption. The research includes an analysis of the facility's energy demand, the design of an appropriately sized system, and an evaluation of the investment's economic viability. Experimental measurements are obtained from the Fusion Solar software system, which is used for real-time monitoring of photovoltaic systems. The photovoltaic system for which data was recorded has a capacity of 547.69 kW, and its data was utilized for the simulation of a combined power generation and storage system. The study determines the optimal system capacity, the amount of energy saved, and the viability of the combined system. Key parameters of the study include the constraints imposed on energy production systems by the Independent Power Transmission Operator (ADMIE), the operating principles and main characteristics of energy storage systems, as well as the estimation of market revenues and expenses for the project's viability.

Keywords

ESS, photovoltaic system, experimental measurements, electrical energy, energy production diagramm

EVALUATION OF "DIFFRACTION BASED SCATTERING" TO PREDICT THE ACOUSTIC FIELD AROUND AERODYNAMIC SURFACES

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ABSTRACT

In the present thesis, the acoustic field around complex shapes was studied using a method which calculates sound diffraction by utilizing the solution for the simple wedge geometry in the wave equation. The method can be applied to all convex, polyhedral, and rigid objects through EDTOOLBOX (an open-source code that operates within the MATLAB programming environment). Initially, the geometry of a cylinder with a point source was introduced into the program for various frequency and receiver cases. Variations in the cylinder's geometry were then used to study the convergence of the method concerning key numerical parameters. Next, a comparison was made between the method and an analytical solution for the cylinder in the illuminated region, where the two methods were found to be in reasonably good agreement. Subsequently, the geometry of a wing was introduced into the program, again for various frequency and receiver cases. Finally, an attempt was made to predict the frequency response of the wing using a machine learning application (MATLAB's Regression Learner). Predictive models were created over a wide frequency range with fairly high accuracy, which seems to have great potential as it offers smaller computational time compared to EDTOOLBOX original calculations. Overall, this diffraction calculation method appears promising since, theoretically, it can be used for all geometries and across all frequency ranges.

Keywords

Acoustic field, diffraction, wing, prediction models, scattering

SIMULATION OF THE MIXING AND REACTING FIELDS OF TAY-TYPE GAS TURBINE COMBUSTOR FOR METHANE/AIR AND N-HEPTANE/AIR MIXTURES UTILIZING THE EDDY DISSIPATION MODEL IN AN OPEN-SOURCE SOLVER

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ABSTRACT

This thesis focuses on the simulation of the isothermal mixing field and the reacting flow within a Tay-type gas turbine combustor (Rolls-Royce Tay). Initially, an overview of combustion is provided, detailing key combustion parameters and the classification of combustion problems. Subsequently, the primary types of combustors commonly employed in aeronautical applications for aircraft propulsion are introduced, along with an emphasis on their fundamental design requirements. The governing equations for combustion phenomena, including the conservation of mass, momentum, and species mass, are presented and appropriately adapted for application to the current study. The simulation employs the Eddy Dissipation Model (EDM) to account for the interaction between turbulence and chemical reactions, while turbulence itself is modeled using the Lilly-Smagorinsky Large Eddy Simulation (LES) approach. Two separate simulations were conducted with n-Heptane and Methane as the fuel respectively for the study, and the chemical reactions were modeled using a two-step reduced reaction mechanism. This simplified mechanism allows for the accurate prediction of major species, such as CO and CO2, while maintaining computational efficiency. The boundary conditions used in the simulation are detailed, alongside the simplifications and assumptions made to streamline the problem. The geometry was created using the Fusion360 software package and in detail explained in this thesis. Then, the mesh was created using the utilities provided by OpenFOAM such as blockMesh and snappyHexMesh. Lastly, the numerical simulations were executed on the open-source platform OpenFOAM. The results were compared with the experimental measurements of

Heitor and Whitelaw [1]. In conclusion, the thesis presents key findings, discusses the agreement between simulation and experimental data, and offers suggestions for future research to further refine and expand upon this work.

Keywords

Gas Turbine Combustors, Computational Fluid Dynamics (CFD), OpenFOAM, Eddy Dissipation Model (EDM), Large Eddy Simulation (LES)

EXPERIMENTAL INVESTIGATION OF THE CSUTHERMAL FLOW FIELDS DOWNSTREAM OF A BLUFF BODY CONFIGURATION, SUITABLE FOR STRATIFIED FLAME STUBILIZATION OF PROPANE-AIR FLAMES

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ABSTRACT

In this student thesis, the theoretical background, the measuring equipment, and the laboratory experimental setup used to study the flow field in a conical bluff body, suitable for the stabilization of stratified air propane flames, are presented. This experimental facility was designed and constructed at the Technical Thermodynamics Laboratory of the University of Patras.

The basic theoretical background of the combustion process, as well as the main mechanisms by which it is governed, are presented first. In particular, the various scientific fields that contribute to the combustion process are described and an extensive description of the classification of the combustion processes is given. Moreover, stoichiometric combustion and flammability limits are discussed.

Furthermore, flame-stabilization bluff bodies are presented. Their operating principle is analyzed and the main characteristics of the flow, when bluff bodies interfere, are highlighted.

In addition, the experimental setup and the equipment required for the implementation of the experiments are presented. Emphasis is given on Particle Image Velocimetry (PIV) while its operation principles and the basic elements are highlighted.

Additionally, the mixing field is studied with the help of PIV and the distributions of velocities, turbulence intensity and rate of change of velocity are extracted. The cases studied have different air and fuel flow rates, in order to assess their effect of mixture strength on the developing flow field.

Finally, a discussion on the flow field distribution is made, followed by the main conclusion of the study.

Keywords

Combustion, Particle Image Velocimetry, Bluff bodies flameholders, Mixture Stratification, Isothermal flow fields

STUDY OF THERMAL COMFORT CONDITIONS IN OUTDOOR OR/AND INDOOR SPACES

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ABSTRACT

Thermal comfort in outdoor spaces within urban environments is a critical issue in modern urban life, especially in an era where the impacts of climate change, such as rising temperatures and the increased frequency of extreme weather events, combined with the Urban Heat Island (UHI) effect, significantly worsen living conditions in cities. In this context, the analysis and improvement of thermal conditions in shared public spaces are becoming increasingly important, as urban areas serve as hubs of social activity and interaction for more and more people.

This study focuses on investigating existing conditions and implementing targeted interventions to improve thermal conditions in the Voud neighborhood, a district within the city of Patras, using computational tools to simulate and evaluate thermal conditions during the summer months. The Predicted Mean Vote (PMV) and the Physiological Equivalent Temperature (PET) were used as thermal comfort indexes of choice for the quantitative assessment of thermal conditions.

In this study, thermal conditions during the summer were examined in the existing state, followed by simulations to investigate the impact of various factors and interventions for improving thermal comfort, utilizing the capabilities of the computational tool RayMan. To accurately study the space, modeling and parameterization of its elements were performed within the software, starting with an initial simulation of the existing conditions and followed by a scenario-based analysis of the impact of different parameters. Specifically, the effects of different wind speeds, relative humidity, the Bowen ratio, as well as other interventions, such as increased vegetation and the use of high-albedo materials, were examined. The increase in evapotranspiration proved to be a significant parameter contributing to the improvement of thermal comfort, as vegetation and water availability reduce sensible heat, thereby decreasing thermal discomfort, especially during periods of extreme heat. Additionally, the

extensive use of cool materials contributes to the reduction of surface temperatures and the mitigation of heat accumulation, thus reducing thermal discomfort during the day.

The results of the study showed that proper design and the implementation of interventions, such as vegetation and cool materials, can significantly improve thermal comfort in an outdoor space. Furthermore, the use of computational tools for simulating and evaluating thermal conditions is an integral part of modern urban design, as it enables evidence-based decision-making and the optimization of public spaces. Lastly, the study highlights the importance of thermal comfort in improving the quality of life in urban centers and the need for strategies that consider climatic conditions and the needs of city residents.

Keywords

Thermal Comfort, Outdoor Spaces, Urban Heat Island (UHI), Urban Microclimate

MODELING AND SIMULATION OF PEM FUEL CELLS USING OPENFOAM

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ABSTRACT

The dissertation presented aims to build a model that simulates the basic functions of a PEM fuel cell, using the open-source computational tool OpenFOAM. Essentially, the model takes into consideration some of the many physical phenomena occurring inside a PEM fuel cell and tries to simulate them using the capabilities of OpenFOAM package. The model was based on chtMultiRegionFoam, a solver capable of simulating transient fluid flow and solid heat conduction, with conjugate heat transfer between regions, buoyancy effects, turbulence, reactions and radiation modeling. In the beginning, a two fluid flow separated with a porous media was studied. Afterwards, the transfer of protons through the electrolyte was modeled and the concentration of species on the cathode was observed. For the final simulation, both the chemical reaction and the effects of the porous media was modeled. For the derivation of the study, built in tools of OpenFOAM were used, without significant modifications to their code. The project presents the steps of constructing the model, starting with the creation of geometry and mesh, continuing with the mathematical and computational model, and concluding with the analysis of the results.

Keywords

Proton exchange membrane fuel cell, hydrogen, computational fluid dynamics, electrochemistry, OpenFOAM

STUDY AND EVALUATION OF THE WIND POTENTIAL OF THE AEGEAN REGION FOR THE INSTALLATION OF WIND TURBINES

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ABSTRACT

In this study the wind power potential is theoretically calculated in the region of the Aegean Sea. Specifically, the wind data, that is used, came from the National Meteorological Service (NMS) and belonged to the following stations in the Aegean region: Heraklion, Ierapetra, Kastelli, Limnos, Mytilene, Rhodes, Skiathos, Skopelos, Skyros, Souda and Chios. Additionally, the wind intensities of these specific stations that are used for each month of the year belong to a period of at least 40 years.

The wind turbine that is used for the analysis and evaluation of the wind power potential for each station, has a nominal power of Po=3 MW, with its hub at 100m height. Additionally, the wind turbine has a cut-in speed Vc=5 m/s, rated speed V_R = 14 m/s and furling speed V_F = 22 m/s. By using the equation for the Weibull Curve, it is calculated for each month for each station the capacity factor Cp, the total mean power factor ω, the mean power coefficient of intermediate stage ω_1, the mean power coefficient for the area nominal function ω_2, the shape coefficient k, the scale coefficient c and the available wind energy for each month En. Furthermore, it must be mentioned that the capacity factor Cp should be around the value of the average annual rate to all the months, which according to the tables that occur, does happen.

Then the results are shown in tables and graphs, as well as the graphs that depict the wind's direction in each area. Also, the payback time is estimated for each station. According to the tables and results that occur it is concluded Kastelli provides a good payback time, meanwhile East Crete, Heraklion and Ierapetra, and Skopelos do not. Good payback times provide Chios, Mytilene, Rhodes, Skyros and Limnos. The remaining stations provide payback times between 8 – 9 years. Finally, it is known that the payback times depends and can be affected by the availability coefficient.

Keywords

wind turbine, wind potential, Weibull curve, capacity factor, payback time

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING WALL OR CEILING GRILLES OF JET AND VALVE TYPE OF DIFFERENT DIMENSIONS

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ABSTRACT

In this thesis, the air flow through four different types of air conditioning nozzles is studied, with two of them being wall and jet type and the other two being circular and roof type. During the calculation of the grilles, the characteristic variables expressing their operation within an enclosed space were determined. In particular, the velocity distribution, lift, drop, diffusion and pressure drop of the air jet are analyzed. Furthermore, for the proper calculation of the variables, initial and final conditions are defined that appropriately serve the space specifications and the conditions we have defined, reducing the unknown parameters in the mathematical equations used. This process was carried out in a computational simulation using the computational fluid dynamics program Ansys Fluent. Finally, the values found from the study were commented on and conclusions were drawn regarding the use of stacks for ventilation and air conditioning of a room for human use and the thermal comfort they can provide.

Keywords

Vents, Air flow, Computational fluid dynamics, Ventilation, Finite elements

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING VENTS WITH LINEAR GRILLES WITH VANES FOR THE REGULATION OF THE FLOW DIRECTION AND ORIFICE DIAPHRAGMS REGULATED WITH OPPOSITE MONING VANES

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ABSTRACT

In this thesis, the objective is to analyze the airflow from grilles in a room with specific dimensions, in order to calculate and evaluate their characteristics. These characteristics include velocity distribution, throw, rise, drop, spread and pressure drop(DP) of the airflow. The upper limit of the airflow was determined based on the maximum critical velocity exiting the grille (Vc = 10 m/s). The area of interest to be studied is where one sits comfortably and in this study it was set at an air velocity of 0.5 m/s. The turbulence model used to predict the area is the Realizable k-ε. In addition, the turbulence models, discretization methods and algorithms for solving the equations are presented. A comparison was made between grids with different geometry and characteristics. The grilles were designed in SOLIDWORKS, while the computational investigation and results were performed with ANSYS Fluent.

Keywords

Computational fluid dynamics, grille, discretization, velocity distribution, air beam

USE OF ADAPTIVE HYBRID GRIDS FOR THE IMPROVEMENT OF ACCURACY OF FLOW SIMULATIONS

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ABSTRACT

In the field of Computational Fluid Dynamics, the detection of flow features is a major field of research, as understanding the nature and dynamics of flow features enables the development of more effective methods to detect and predict fluid behavior in various fields, such as aerodynamics, climatology, hydrodynamics, and others.Improving the visualization of flow features, which are detected through the application of mathematical sensors, can be achieved by computational grid adaptation.

The present research focuses on the study of multiple flow features of varying intensities, employing specially designed sensors for detection. The flow features investigated in this research include boundary layers, flow separation, vortices, wakes, and jet flows, as well as supersonic flow features such as shock waves, detonation waves, and compression waves. These flow fields are analysed using a sophisticated flow visualization program, while the necessary meshes are generated with an advanced mesh generation program and additional computational tools.

Particular emphasis is placed on the detection of flow features. This process uses mathematical sensors based on spatial differences in a wide range of flow quantities. Subsequently, an additional sensor formula is used, called the Composite sensor. Composite sensors combine elementary sensors of a single flow quantity and are capable of detecting multiple flow features. Sensors are assessed using a quantitative approach based on the calculation of surfaces enclosed by indicative curves and relevant metrics are provided to demonstrate their effectiveness. This evaluation is carried out through the application of the sensors to a diverse range of computational flow fields, which contain both steady state and transient cases.

After studying the flow field, the Initial mesh is then Adapted based on the results from the flow simulation. The new, customized mesh exhibits Refinement or/and Redistribution of prism layers in regions where significant flow features are detected. This mesh adaptation process is guided by sensors, geometric shapes or the parameter y+, which helps to identify critical points of interest. Part of this work focuses on the comparison of the two grids, Initial and Adapted. In particular, it examines how the grid adaptations have been beneficial in enhancing the accuracy of the simulation and the visualization of the flow. This study demonstrates significantly improved representation of flow phenomena in the Adapted mesh, providing better resolution in critical regions and contributing to more accurate and reliable flow analyses.

Keywords

hybrid grids, grid adaptation, flow feature detection, flow sensors, compressible flow

DIVISION OF MANAGEMENT AND ORGANIZATION (FEBRUARY 2025)

PREDICTIVE MAINTENANCE AND LIFECYCLE ASSESSMENT IN OVERHEAD CRANES

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ABSTRACT

This thesis examines the application of predictive maintenance in industrial equipment, highlighting its benefits compared to traditional maintenance methods and how technological advancements contribute to the efficiency and reliability of components. Specifically, it focuses on the environmental impact generated during the life cycle of hoists and the motors of an overhead crane, emphasizing the stages of use and maintenance. Data analysis using artificial neural networks allows for the extraction of mathematical relationships between variables such as pressure and wear, leading to accurate estimates of the remaining useful life of systems. These estimates are used to connect with two scenarios: the first examines traditional maintenance and its associated carbon dioxide emissions, while the second concerns predictive maintenance and the reduction of environmental impacts. With predictive maintenance, components do not reach the point of failure, thus reducing the need for the production of new spare parts and consequently the environmental burdens, enhancing the sustainability of industrial processes in overhead cranes.

Keywords

Predictive Maintenance, Artificial Neural Networks, Environmental Impact, Industrial Equipment, Data Analysis.

DEVELOPMENT OF A RECOMMENDER SYSTEM BASED ON A GRAPH-OF-DOCS REPRESENTATION

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ABSTRACT

This thesis focuses on the design and implementation of a recommendation system based on the representation of textual data in graphs (Graph-of-Docs) while leveraging advanced deep learning techniques, with an emphasis on Graph Neural Networks (GNNs). Recommendation systems are fundamental tools for personalized content delivery and recommendation generation, with applications in e-commerce, social media, and multimedia services.

The study includes a literature review of key recommendation techniques, covering Collaborative Filtering, Content-Based Recommender Systems, Hybrid Models, and the application of Neural Networks in recommendations. Particular emphasis is placed on GNNs as a method of representation learning, as they enable the integration of complex relationships and structured data.

In the practical section, a recommendation system is developed based on the Graph-of-Docs approach, where nodes represent users, products, reviews, and words, while edges capture relationships such as purchases, ratings, and word co-occurrences. The graph is stored and processed using the Neo4j graph database, while word embeddings are generated using Word2Vec.

The system is implemented using GraphSAGE, a node representation learning algorithm for large-scale graphs, trained to predict ratings and improve recommendations. The evaluation results are based on metrics such as RMSE, MAE, and R2, allowing the comparison of the proposed model's performance against more traditional recommendation methods.

The analysis of the results demonstrates that, despite the challenges posed by data volume, the proposed approach successfully structures and models the relationships within the dataset using graph-based representation. The developed system effectively integrates users, products, reviews, and textual information into a unified framework, enabling future refinements. Although the obtained results did not reach the expected performance levels, this is primarily attributed to data limitations rather than the methodological approach itself. We propose further experimentation with an expanded dataset and improved preprocessing techniques to fully exploit the model's potential.

Keywords

Recommender Systems, Graph Neural Networks, GraphSAGE, Word2Vec, Graph-Based Data Representation.

STUDY AND COMBINED USE OF MULTICRITERIA DECISION ANALYSIS METHODS FOR ASSESSMENT OF ENERGY STORAGE TECHNOLOGIES

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ABSTRACT

Over the last decade, the use of Renewable Energy Sources (RES) for electricity generation has become a global strategy to address the climate crisis. However, renewable energy, although inexhaustible, is subject to fluctuations in production as it depends on natural sources such as sun, water and wind. Their sudden integration into energy systems, coupled with increasing electricity demand, has created challenges in terms of generation and grid stability. In this context, energy storage systems (ESS) are a reliable technological solution to ensure smooth operation, flexibility and sustainability of the energy system.

This thesis examines the European energy landscape, with a particular focus on Greece, analyzing power generation sources, transmission and distribution networks, the role of RES, as well as the infrastructure and potential for utilizing energy storage technologies. The fundamental ESS technologies are presented, with an analysis of their characteristics, applications, advantages, and challenges.

Next, the theoretical framework of multicriteria decision analysis (MCDA) is introduced, as it serves as a crucial tool for managing complex energy problems involving multiple criteria and stakeholders. The basic principles of MCDA are outlined, along with an in-depth analysis of the PROMETHEE and ELECTRE methods, which are widely applied in energy-related studies. Following this, a literature review of 14 studies that have employed multicriteria methods to evaluate ESS and other energy applications is conducted. A concise overview of the applied methodologies and research findings is provided, while the evaluation criteria for storage systems are analyzed.

Finally, a case study is carried out, using the ELECTRE Tri and PROMETHEE II methods, in which 10 countries in Southeastern Europe are assessed in terms of their capability to integrate ESS, while 7 different energy storage technologies are also evaluated. Based on the results, the most suitable countries for ESS deployment are Hungary, Turkey, Albania, and Croatia, while the most efficient technologies are determined to be pumped hydro storage, flywheel systems, compressed air energy storage, and lithium-ion batteries. Overall, this study aims to provide valuable insights and a strategic methodological framework for countries seeking to integrate ESS into their energy systems to meet their energy needs.

Keywords

Energy Storage Systems (ESS), Renewable Energy Sources (RES), Multicriteria Decision Making (MCDA), Multicriteria Analysis, Evaluation

DIGITAL INDUSTRIAL TRANSFORMATION AND APPLICATION OF MACHINE LEARNING TECHNIQUES IN PREDICTIVE MAINTENANCE

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ABSTRACT

This paper examines the process of digital industrial transformation and the utilization of machine learning techniques for predictive maintenance, focusing particularly on a real-world application in the Greek industry. Initially, the characteristics of the digital transition are analyzed, and a general three-part framework for digital transformation strategy is presented. Concurrently, the challenges and improvement actions regarding the integration of new technologies, organizational culture, and data management are discussed. The ISA-95 model is examined as a key tool for the structured integration of production systems and information systems to effectively achieve their interconnection and data exchange.

For the practical investigation of the above concepts, the case of a three-parallel-shaft reducer in the ball mill of the "Aluminium of Greece" factory is studied. A technical description of the equipment is provided, common failures and maintenance requirements are presented, and subsequently, the digital transformation process of its maintenance is described. In this context, basic machine learning algorithms are used for predictive maintenance, where the One-Class SVM model is employed for anomaly detection and moving average analysis through linear regression is conducted to identify trends in equipment vibrations. The results confirm the importance of digital transformation and predictive maintenance in improving equipment reliability, reducing maintenance costs, and ensuring the smooth operation of the production process.

Keywords

Digital transformation, Industrial transformation, Machine learning, Predictive maintenance, ISA-95

ARTIFICIAL INTELLIGENCE APPLICATIONS IN CUSTOMER RELATIONSHIP MANAGEMENT

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ABSTRACT

This thesis examines the contribution of artificial intelligence (AI) to customer relationship management (CRM), analyzing how modern technologies are reshaping business practices. Starting from the historical evolution of CRM, it describes the transition from traditional manual data management methods and initial software use to sophisticated systems based on artificial intelligence. The role of AI in improving personalization, automation and data analytics is central, with the goal of optimizing customer experience and boosting sales and marketing.

Integrating technologies such as machine learning (ML), natural language processing (NLP), chatbots, and predictive models provides important tools for businesses to anticipate customer needs and behaviors. Chatbots and virtual assistants improve speed and quality of service, while loyalty programs and sentiment analysis boost customer retention and loyalty. In addition, artificial intelligence makes it easier to create personalized experiences by tailoring offers and content to each customer's needs.

A significant part of the work is devoted to the challenges faced by businesses when adopting AI-CRM systems, such as ensuring privacy and data security, implementation costs, system complexity and the need for businesses to adapt to new technological standards. However, real-world examples, such as applications in e-commerce, finance and telecommunications, highlight the positive impact of AI-CRM systems on businesses that achieve better customer understanding, enhanced loyalty and increased efficiency.

The thesis concludes that AI offers unique capabilities in customer relationship management, offering a strategic advantage for businesses. At the same time, the need for continuous improvement of AI-CRM systems, focused on ethical use, transparency and compliance with regulatory requirements, is underlined. AI is seen as a central driver for future innovation in customer relationship management, creating opportunities for personalized service, proactive management and stronger business relationships.

Keywords

Artificial Intelligence (AI), Customer Relationship Management (CRM), Customer Personalization, Chatbots and NLP, Predictive Analytics

TECHNO-ECONOMIC INVESTIGATION OF THE RECOVERY OF RARE EARTHS ELEMENTS FROM THE BY PRODUCTS OF BAUXITE PROCESSING FOR ALUMINA PRODUCTION

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ABSTRACT

The aluminum industry is a vital sector of Greece's economy, influencing both national and international markets through its production, technological advancements, and economic significance. This thesis provides a comprehensive analysis of the industry, covering the fundamental aspects of aluminum production, market trends, sustainability challenges, and economic prospects. The research begins by defining the essential components of aluminum manufacturing, including bauxite mining, alumina refining, and aluminum processing, and examines their role in the global supply chain. The classification of aluminum as a Critical Raw Material (CRM) by the European Union is explored, with an emphasis on its economic and technological importance in industries such as construction, aerospace, and energy infrastructure.

An extensive evaluation of the international and European aluminum markets is conducted, analyzing production trends, price fluctuations, and trade dependencies. The study also assesses the pros and cons of aluminum, focusing on its physical properties, its advantages in industrial applications, and the environmental impact of its extraction and processing. A distinction is made between semi-final and final aluminum products, examining their use across various sectors, including manufacturing, transportation, and packaging.

The production process of alumina and aluminum is thoroughly investigated, detailing the Hall-Héroult process, primary and secondary processing techniques, and the energy-intensive nature of aluminum smelting. A critical assessment of energy consumption, carbon emissions, and cost efficiency in aluminum production is provided, with a particular focus on recycling as a sustainable alternative. The study also examines aluminum by-products and waste management strategies, with a special emphasis on red mud disposal and its environmental consequences.

The main component of this research is the feasibility study of a Scandium Oxide (Sc_2O_3) production pilot plant, which explores the economic and technical viability of scandium recovery from bauxite residues. The study assesses cost structures, investment requirements, energy consumption, and pricing strategies, providing an in-depth economic evaluation of scandium's potential role in high-tech applications in modern technological and industrial society. By analyzing different production scenarios the research highlights strategic opportunities for integrating scandium recovery into Greece's aluminum industry.

The thesis concludes with a discussion on the future of the Greek aluminum sector, offering insights into technological innovations, policy recommendations, and pathways toward sustainable development. It emphasizes the need for investment in low-carbon technologies, improvements in recycling efficiency, and the strategic integration of high-value material recovery processes to enhance Greece's industrial competitiveness.

Keywords

Aluminum, production, critical raw materials, energy consumption, environmental impacts, sustainable development, scandium oxide, feasibility study, Greek industry, circular economy, economic assessment

DIVISION OF APPLIED MECHANICS, TECHNOLOGY OF MATERIALS AND BIOMECHANICS (JUNE 2025)

LIFE CYCLE ANALYSIS AND SUSTAINABILITY ASSESSMENT OF LIQUID HYDROGEN STORAGE TANKS

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ABSTRACT

In today's era, multiple innovative applications are being developed, aiming to mitigate the environmental impacts of existing technologies. One such innovation is the aircraft powered purely by hydrogen. Although the operational phase of this aircraft accounts for most of the percentage of its environmental impacts, the contribution of the production stage of the necessary subsystems required for its operation, should not be neglected. This study assesses and evaluates the sustainability of 12 different production scenarios for a hydrogen tank, using tools such as Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). The basic structure of the hydrogen tank consists of the subsystems of the outer and inner tank, their supports, and the necessary insulating materials. The variations of the main materials used in these subsystems is what creates the 12 different alternatives for the tank. The LCA and LCC analyses were performed using SimaPro software. Environmental impacts were examined using the ReCiPe 2016 Endpoint (H), IPCC2021 GWP100 and Cumulative Energy Demand (CED) methodologies. The performance of the production alternatives was evaluated based on their weight, while for the economic evaluation, a customized cost method based on real market prices for materials and energy was used. The optimal tank production scenario was calculated based on the values obtained from the above methods, utilizing the multi-criteria decision-making method R-TOPSIS. From the entirety of the above study, it is concluded that the production where the inner and outer tank subsystems are made of aluminium alloy and the outer tank supports are made of stainless steel is the optimal one. Meanwhile, the material

used for internal insulation causes the greatest environmental and economic burden compared to the other materials of the tank.

Keywords

Hydrogen Tank, Sustainability, Composite Materials, Life Cycle Assessment, Multi-Criteria Decision-Making Method R-TOPSIS.

DESIGN, ANALYSIS AND OPTIMIZATION OF A FIXED WING UAV FOR A SPECIFIC MISSION PROFILE

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ABSTRACT

Purpose of this work is the development of a design algorithm for an unmanned aerial vehicle (UAV) for a specific flight envelope (surveillance mission), preceded by the study of conventional aircraft design algorithms by Daniel P. Raymer, J. Roskam, and M. Sandrey. Additionally, a literature review was conducted regarding unmanned aerial vehicles (UAVs — what they are, their categories and applications, etc.), in order to gain a comprehensive understanding of the UAV design for this project.The design process is divided into three stages: Conceptual Design, Preliminary Design, and Detailed Design. The design algorithm to be developed will only address the first two stages (i.e., Conceptual and Preliminary Design). The primary stage of the design is the analytical calculation of the aircraft's weights (takeoff weight, payload weight, fuel or battery weight, and empty weight). Once the weights are calculated, the next step is to compute the wing loading (W/S) and the engine thrust (T/W or W/P), in order to derive the geometric characteristics of the aircraft (wing area, tail area, fuselage length and diameter).In parallel with the computation of the geometric characteristics of the aircraft, a study is conducted regarding the airfoil selection for both the wing and the tail, aiming to identify the most suitable airfoil based on the Reynolds number during flight and the aerodynamic coefficients that must be achieved.Once the airfoils are selected and the geometric characteristics are calculated, the aerodynamic analysis of the aircraft takes place — first through analytical calculations, and then through Low- and High-Fidelity Analyses using Computational Fluid Dynamics (CFD). After the final calculation of the aerodynamic coefficients, the aircraft's performance is calculated for each phase of flight (flight envelope).

Keywords

Unmanned aerial vehicles, aircraft preliminary design, dynamic analysis, aerodynamic analysis, Solidworks, Ansys fluent

STATISTICAL INVESTIGATION OF THE USE OF LASER FOR THE SURFACE TREATMENT OF COMPOSITE MATERIAL STRUCTURES

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ABSTRACT

The ever-increasing demand for more durable and lighter constructions has led to the development of new materials. Among these are composite materials, which already have widespread applications in various industries and uses. Particularly noteworthy are Carbon Fiber Reinforced Polymers (CFRP), which are employed in numerous construction sectors requiring lightweight structures with high mechanical properties. For instance, they are used to build primary structural components in commercial airplanes, fighter jets, and helicopters.

Today, the aerospace and aeronautics industry represents the largest market for advanced composite materials, and, according to 1984 data, accounts for 75% of the global consumption of these materials. This focus is not arbitrary; it is primarily due to the reduced weight and operational cost benefits offered by composite materepairials.

As the application of composite materials in various constructions increases, the need to develop methodologies for their effective surface treatment, in order to improve the mechanical and physical properties of the materials and ensure the maximization of their performance after treatment.

This thesis presents the statistical investigation of the surface treatment of composite material structures using laser. This method enables the automation of the process and optimization of the mechanical properties.

More specifically, using a green laser (λ = 532 nm) and applying the Box-Behnken Design, 15 experiments were conducted to determine the optimal settings. Independent factors considered included: scanning speed, frequency-power, and the distance between scans using a spiral scanning pattern. The experimental results of the specimens were analyzed using Box-Behnken statistical methods and Analysis of Variance (ANOVA), separately.

Keywords

Carbon Fiber Reinforced Polymer-CFRP, Statistical Analysis, Analysis of Variance-ANOVA, Response Surface Methodology-RSM, Box-Behnken Design, Green Laser

CALCULATION OF THE INTERLAMINAL FRACTURE TOUGHNESS USING THE DIGITAL IMAGE CARELATION METHOD

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ABSTRACT

Composite materials have become essential in modern engineering due to their excellent properties, such as high specific strength, stiffness, and tailored anisotropy. They are extensively used in aerospace, automotive, marine, and civil infrastructure applications, where materials with low weight and high durability are required. The major issue with composite materials is their primary failure mechanism—delamination. Fracture mechanics science is used to calculate the interlaminar fracture toughness of such materials. The purpose of the present thesis is to calculate the interlaminar fracture toughness of a composite specimen with a crack, subjected to Mode I loading using the Digital Image Correlation (DIC) method. Through DIC, the displacements of the specimen around the crack will be extracted and subsequently imported into a MATLAB code in order to calculate its interlaminar fracture toughness.

Keywords

Fracture mechanics, Digital Image Correlation, Energy release rate, Interlaminar delamination, Stochastic Pattern.

NUMERICAL SIMULATION OF DAMAGE DETECTION IN A COMPOSITE STRUCTURAL COMPONENT USING VIBRATIONAL RESPONSE

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ABSTRACT

This thesis deals with the numerical detection and classification of fatigue damage in a thermoplastic reinforced structure made of composite fibrous material, using Frequency Response Functions (FRFs). This was achieved by modeling the vibrational behavior in the finite element software LS-DYNA, where simulations were conducted for both the healthy condition and various stages of progressive damage due to repeated loading.

The methodology applied to the examined structure was developed in a previous undergraduate study, in which the vibrational behavior of a thermoplastic material specimen under random excitation (white noise) was investigated. In particular, several metrics were assessed in order to identify the most appropriate one for damage monitoring. It was shown that the natural frequencies of the structure are sufficient for studying the problem, and the methodology was scaled up to a more complex and realistic level, simulating the actual conditions of a structural component.

To better understand the dynamic behavior of the structure, a parametric study was designed and carried out, initially examining the effect of boundary conditions (fixed–free, free–free), followed by the position and nature of the excitation (within a specified frequency range), and the locations of the response data collection points. The collected data were converted into Frequency Response Functions, as the excitation used does not include white noise, and therefore the traditional Power Spectral Density (PSD) approach was not suitable.

Damage detection was based on the application of a simple yet highly sensitive damage indicator, which was designed to accurately detect changes in the structure's dynamic response. In addition to the damage indicator, four semi-empirical equations describing the damage evolution in fibrous composite materials were evaluated, aiming to select the most

representative model for describing the mechanical degradation of the thermoplastic reinforced structure. The evaluation focused on each equation’s ability to fit the computational data and reflect the actual progression of damage.

The correlation of the damage indicator with the damage stages, as derived from the evolution of loading cycles, enabled the classification of the material's condition into four primary categories: matrix cracking, delamination, extensive delamination, and fiber breakage. To classify the data into these stages, five machine learning algorithms were implemented: Support Vector Machine (SVM), k-Nearest Neighbor (k-NN), Ensemble Method (Bagging), Naïve Bayes, and the decision tree algorithm C4.5. Each algorithm was evaluated in terms of its ability to classify new, unseen data, as well as its potential to generalize its results to similar damage diagnosis problems.

In conclusion, this thesis demonstrated that frequency-based structural health monitoring is a highly effective tool for complex reinforced structures. The use of finite element software allowed for accurate simulation of various damage states, while the selection of appropriate natural frequencies and application of a damage index significantly simplified the damage detection process. The integration of machine learning techniques further enhanced the structural condition assessment, offering satisfactory accuracy at a low computational cost, provided the damage stages are known in advance. With the appropriate model selection, sufficient generalization was achieved, proving the potential for extending the methodology to more complex problems involving intricate geometries and different materials. Overall, the work provides a comprehensive framework for monitoring and assessing damage based on dynamic response, enhancing the ability for early diagnosis and prevention of failures in engineering systems.

Keywords

Thermoplastic material, Reinforced structure, Fatigue, Frequency Response Function, Damage Index, Damage Detection, Damage Classification, Finite Element Models, Machine Learning Algorithms.

INVESTIGATION OF DYNAMIC BEHAVIOUR OF A PLATE WITH MECHANICAL RESONATORS

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ABSTRACT

Additive Manufacturing (AM) or 3D Printing has made significant progress and is one of the most promising and innovative technologies. This technology is based on the logic of creating structures in layers, giving it the ability to manufacture structures in complex geometries, sometimes unattainable with traditional manufacturing methods, which are based on the logic of removing material. This advantage, combined with the ability to utilize a wide range of materials, as well as achieve high dimensional accuracy, has made it possible to use the technology from the private to the aerospace industry level.

In this Thesis, the parameters affecting the printing of structures using Fused Deposition Modeling method and Polylactic Acid (PLA) material are studied and evaluated. After determining the appropriate parameters, structures are produced and their dynamic behavior is studied. The aim is to produce structures that work in vibration-damping applications. A "mechanical jack"-shaped element is designed, carrying a stem with a cylinder in its center. These elements are intended to be attached to a plate and act as Tuned Mass Dampers (TMDs), which will absorb the amplitude of plate's oscillation.

The computational simulations were carried out using the Finite Element Method (FEM) within the ABAQUS environment. The computational models developed contributed to understanding the complex dynamic behavior of 3D-printed plates with multiple tuned mass dampers, as well as to the design of the experimental procedure conducted as part of this thesis. The study covers multiple levels, starting from simple flat geometries to more complex configurations, with the ultimate goal of combining the developed components and observing the damping phenomenon through multiple TMDs.

Keywords

Additive Manufacturing (AM), 3D-Printing Parameters, Frequency Response Function, Tuned Mass Dampers (TMDs)

DESIGN, ANALYSIS AND OPTIMIZATION OF A DEPLOYED NANOSATELLITE ANTENNA

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ABSTRACT

This thesis presents the design, analysis and optimization of a deployable nanosatellite reflector antenna. It begins with an overview of the various types of reflective surfaces commonly found in deployable reflector antennas. Following this, 4 design concepts are proposed and evaluated based on volume and mass requirements, deployment reliability and mechanism complexity. Among them an umbrella type reflector was selected for further development due to its advantages. In the rest of the thesis a two-stage modeling approach was adopted. Initially, a simplified 1-rib model was developed to analyze the reflector kinematically and structurally. Lessons learned from this model were applied in the design and optimization of the final 20-rib reflector. The complete model was subjected to kinematic analysis, modal analysis in the stowed and deployed configuration and quasi-static structural assessment under simulated launch conditions. The analysis confirmed successful deployment and structural viability. Modal analysis results, in both stowed and deployed configuration, showed acceptable natural frequencies and quasi-static analysis results demonstrated that the reflector is able to withstand 25g acceleration along its axial direction and 30g of acceleration along its two lateral directions.

Keywords

Nanosatellite antenna, Aerospace Engineering, Deployable mechanism, Radial-rib reflector, Kinematic analysis

DIVISION OF DESIGN AND MANUFACTURING (JUNE 2025)

DEVELOPMENT OF AN APPLICATION FOR PROPELLER FAULT DIAGNOSIS IN A QUADCOPTER AIRCRAFT USING MACHINE LEARNING METHODS IN REAL TIME

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ABSTRACT

This diploma thesis presents the design and development of an application for fault detection and fault severity characterization in a quadcopter UAV using stochastic vibration signals from an onboard accelerometer and Machine Learning (ML) methods. The application focuses on detecting and characterizing propeller-related faults, which, despite being common, are difficult to identify at an early stage, directly affecting flight safety and the overall airworthiness of Unmanned Aerial Vehicles (UAVs). The application is structured into six main modules: (1) the Data Acquisition (DAQ) module, where users can collect UAV data and perform an initial analysis; (2) the AR Modeling module, enabling the user to perform dynamic identification of parametric AutoRegressive (AR) models using established modeling criteria; (3) the Database module, where users can process stored signals for non-parametric identification of the UAV and create new signal and AR model files; (4) the Training Phase, where the supported Multiple Model (MM) methods for fault detection and characterization are trained; (5) the Detection module, which implements unsupervised ML algorithms to detect potential faults in offline mode using Statistical Time Series (STS) MM methods based on Power Spectral Density (PSD) and AR model features (U-MM-PSD & U-MM-AR). These MM methods utilize two distance metrics (Euclidean & Kullback-Leibler) and three distance combination rules (Min, Max & Sum); and (6) the Fault Identification module, where supervised ML algorithms are applied based on MM-PSD, MM-AR, PCA-MM-AR, and robust

ML methods such as SVM-AR & k-NN-AR for fault severity characterization, in both offline and real-time batch modes. The vibration signals used in this study were acquired using a triaxial accelerometer at a sampling rate of 1024 Hz with a length of 61440 samples (60s each), mounted on a DJI Mavic 3 quadcopter. Three fault scenarios were examined (80 measurements each) — ranging from early-stage to severe faults — including blade tip breakage (Damage A), tip erosion (Damage B), and surface abrasion (Damage C), and were compared with 80 healthy-state signals in offline mode. For fault detection, assuming a common FPR of 5.0%, the U-MM-PSD method achieved a best detection rate of 86.1% using the Sum rule. The U-MM-AR method achieved a best detection rate of 88.3% using both Euclidean distance with Sum rule and Kullback-Leibler distance with Min rule. Regarding fault severity characterization in offline mode, MM-AR achieved 65.8% overall accuracy, PCA-MM-AR 71.7%, SVM-AR 79.6%, and k-NN-AR 74.6%. Finally, the ease and speed of using the application for real-time fault characterization with the MM-AR method during in-flight operation were evaluated and are demonstrated in a supporting video.

Keywords

Application development, Quadcopter, Unmanned Aerial Vehicle, propeller fault, stochastic vibration signals, statistical time series methods, dynamic identification, fault detection, fault severity characterization, Real Time, robust Machine Learning Methods

DESIGN AND DEVELOPMENT OF DIGITAL TWIN ARCHITECTURE FOR ADAPTIVE AUTOMOTIVE SUSPENSION

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ABSTRACT

Transportation and Logistics is one of the most important aspects of Manufacturing and everyday life. More specifically a big percentage of transportations is based on road vehicles (private cars, goods transfer vehicles, etc.). On the other hand, the network of land lines connecting the various destinations differ significantly and their maintenance is very difficult. Furthermore, the condition of the road network plays a key role to the transportation of humans and goods as well. Automotive manufacturers in an attempt to constantly integrate cutting-edge technologies to the newer generations of automobiles, have designed and developed smart solutions for adapting key parameters of car suspensions based on the road feedback. However, such solutions are still in their infancy, providing fertile ground for further research. Consequently, taking advantage of the current industrial revolution, also known as Industry 4.0, as well as the digital technologies introduced, new opportunities emerge. Smart and fully connected vehicles in the future will be capable of collecting various data regarding the status of the road as well as the driving conditions and based on advanced simulation techniques, such as Digital Twins, to actively adapt key parameters of the car suspension, in order to maximize comfort, ensure the best possible car performance, minimize fuel consumption etc.. Therefore, the scope of this thesis is to design and develop a Digital Twin architecture for the modelling of automotive suspensions, the simulation based on input from the physical vehicle as well as the generation of suggestions for adapting the vehicle suspension parameters.

Keywords

Industry 4.0, Digital Twin, Simulation, Adaptation, Smart Suspension

DESIGN AND MANUFACTURING OF A VERSATILE ROBOT END-EFFECTOR, BASED ON THE RIGID CHAIN ACTUATOR, FOR AUTOMATED PACKAGING OPERATIONS

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ABSTRACT

In today's competitive, high-mix market, manufacturers must deliver a widening spectrum of product variants at ever-shorter lead times. This highlights the need for industrial automation with pioneering handling and cognition capabilities able to handle personalized products and orders. These reformations become more pronounced in fully dynamic scenarios, such as logistics and packaging of personalized orders, where frequent tool changes and parameter reconfiguration are required. This thesis addresses the need for flexible end-effectors by proposing a gripper based on the rigid-chain principle. A one-way folding chain can be extruded and get access into confined pallet spaces to grasp, support, transfer, and release items without requiring any hardware modifications per variant. A use case originating from the metal-production industry, which deals with the packaging of architectural extrusion profiles, is used to validate the gripper's working principle. The gripper is intended to equip robot arms that bi-manually handle aluminum profiles, stacking them into customer-oriented pallets. A physical prototype was implemented and tested, validating the proposed solution's design principles and showcasing the potential of the concept for the logistics sector.

Keywords

Automation, grippers, end-effector, palletizing, rigid chain actuator

THERMAL-TRIBODYNAMIC ANALYSIS OF SPUR GEAR PAIR USING CORRECTION FACTORS

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ABSTRACT

The aim of this thesis is to study produced vibrations in a pair of spur gears considering rough anisotropic tooth surfaces, use of lubricant and temperature effects on it from heat created by friction. A thermal-tribodynamic model was developed, consisting of two sub-models for calculating the system response and modeling the contact between the meshing gears teeth, as a part of the meshing stiffness. The contact model is utilized to calculate the contact stiffness and the produced friction between gear teeth. To determine the required contact parameters, the model relies on work done by previous researchers on EHL line contacts. To avoid solving the complex Reynolds equation, the load sharing method of (Gelinck & Schipper, 2000), was used in tandem with the statistical model for rough surface contacts of (JOHNSON, GREENWOOD, & POON, 1971) and gear tooth kinematic equations from (Wang & Cheng, 1980). To accommodate for anisotropic surfaces, non-Newtonian lubricant behavior and heat generation, correction factors for each were employed. After calculating the meshing stiffness for the single and double teeth meshing periods. The dynamic response is determined by solving the equations of motion represented in state-space and numerically solved with the fourth-order Runge-Kutta method. This model includes the equations of motion for each gear along with their respective shafts. The elasticities of the contact between the meshing gear teeth, shafts, and bearings are modeled as forces from equivalent torsional and compression springs. The effect of various rotating speeds, loading torque, gear ratio, surface roughness, use of different lubricants, surface anisotropy coefficients and oil bath temperature on both sub-models was also evaluated.

Keywords

Spur-Gears, Tribodynamic Model, EHL, Load-Sharing, Correction Factors, Non-Newtonian Lubricant.

SIMULATION AND ANALYSIS OF THE CHILL-DOWN PROCESS FOR THE DESIGN OF A HANDLING AND DISTRIBUTION CRYOGENIC SUBSYSTEM

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ABSTRACT

This thesis investigates the simulation of a cooldown procedure for vital subsystems, such as valves, couplings, pipes and a hydrogen panel, from ambient temperature to 5% of steady state temperature at cryogenic conditions in order to minimize the boil-off of liquid hydrogen that will be inserted afterwards. The proposed procedure contains a two-step cooling strategy embracing an MBSE approach, beginning with the feed of liquid nitrogen (LN2) in the procedure with the scope to reduce the temperature up to its boiling point which is well inside the cryogenic region. Finally, gaseous helium (GHe) is used in the last phase to plummet the panel's average temperature to 5% of the steady state temperature.

The calculations of mass quantity and time duration for each substance used in the cooldown process are characterized as primary objectives of this research. The cooling strategy is designed to optimize temperature gradient, establishing smooth transitions between phases and eliminating thermal stresses. By calculating the exact quantities of LN2 and GHe at each step, this thesis provides a detailed analysis of the mass demands and the time-dependent behavior of the cooldown process while documenting the phase behavior of the substances in real time inside the application. The findings contribute to the broader understanding of cryogenic engineering by proposing an optimized cooldown procedure with the goal of minimal liquid hydrogen boil-off gas.

Keywords

Chill-down, helium, nitrogen, subsystems, MBSE

FUEL CONVERSION ANALYSIS OF A FOUR-STROKE MARINE DIESEL ENGINE USING COMBUSTION MODELS

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ABSTRACT

Traditional marine diesel engines, while reliable and powerful, are significant contributors to greenhouse gas emissions and local pollutants. The maritime industry faces increasing pressure to reduce emissions while maintaining high engine performance, especially in consideration of tightening global environmental regulations. Exploring alternative fuels such as hydrogen presents a promising avenue, but requires careful simulation and analysis to ensure feasibility, efficiency, and safety.

This study addresses the challenge of evaluating various hydrogen integration strategies into a conventional marine diesel engine platform. In this study, a baseline simulation model of the MAN 32/40 marine diesel engine was developed using ANSYS Forte. This model served as the foundation for investigating the effects of hydrogen integration through five additional fueling configurations. In all cases, hydrogen was introduced as a premixed fuel, while diesel was direct injected. The configurations included one model utilizing hydrogen autoignition under preheated intake conditions, one employing spark-ignited hydrogen, and three dual fuel models combining hydrogen and diesel, which were differentiated by the proportion of each fuel. Across all simulations, the aim was to maintain the engine power output at the range of the base model. The analysis focused on in-cylinder pressure profiles and emissions characteristics, offering insights into the combustion behavior and environmental impact of each fueling strategy.

The simulation results demonstrate that hydrogen, whether used as a primary fuel or in dual-fuel configurations with diesel, can substantially reduce emissions, particularly carbon-based pollutants, while maintaining the engine's power output. However, the outcomes also reveal important complexities. Given the large displacement and high fuel demand of an engine like the one simulated, some results diverge from initial expectations. These deviations can be attributed to the engine's scale and the high volumetric flow rates required, which influence combustion dynamics and fuel-air mixing differently than in smaller engines. The findings suggest that while hydrogen shows strong potential for decarbonizing marine propulsion, the behavior of alternative fuels must be interpreted in the context of engine size and operating conditions. Overall, the study underscores the feasibility of hydrogen integration and highlights the importance of engine-specific optimization when transitioning to cleaner fuel technologies.

Keywords

Marine Engine, Combustion Model, Fuel Conversion Analysis, Hydrogen, Emissions

DESIGN AND OPTIMIZATION OF A STRUCTURAL COMPONENT FROM THE AUTOMOTIVE SECTOR USING MACHINE LEARNING METHODS

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ABSTRACT

In the 21st century, the development of components focusing on passengers' safety, total weight minimization and reduced environmental impact is a primary objective of the automotive sector. The A-Pillars, the frontal columns that support the vehicle's roof and windshield, are no exception since they ensure the passengers' safety and influence the total environmental footprint of the vehicle. The purpose of this thesis is the development of a Finite Element Analysis (FEA) surrogate model that will predict the static and dynamic response of the A-Pillar when subjected to mechanical loads, employing Machine Learning (ML) algorithms. The thesis begins with a theoretical overview of the concepts and algorithms that will be used subsequently. Afterwards, the two types of datasets; a numerical and an image-based one, that will be fed to the ML methods are extensively presented. Then, the feature evaluation process on the numerical dataset is conducted, in which the features are assessed based on their significancy, and only the essential ones are retained for the succeeding training phase. After the preparation of data, ML models are trained on the numerical dataset to predict its targets with accuracy and subsequently they are evaluated based on their performance on predicting unseen instances. Thereafter, the image predictive models are trained, whose objective is the generation of contour plots depicting the simulation results onto the deformed shape of the A-Pillar frames. A separate model compromising neural networks is trained to predict the legend values that will accompany the generated images. The final main chapter of this thesis is dedicated to the selection process of the final model configurations, achieved by analyzing the impact of various hyperparameter combinations on model performance. Through this process of manual tuning the optimal model configuration is identified. The thesis concludes with a summarization of the analysis that was conducted, mentioning the challenges that have been encountered through the

process and suggesting modifications that can improve further the models' performance in future researches.

Keywords

A-Pillar, Machine Learning, Finite Element Method, Surrogate Models

ROBUST FAULT DETECTION AND IDENTIFICATION IN A QUADCOPTER PROPELLER UNDER VARYING OPERATING CONDITIONS VIA MACHINE LEARNING METHODS

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ABSTRACT

This thesis focuses on the detection and identification of small-scale faults in a quadcopter unmanned aerial vehicle (UAV) propeller under varying operating conditions The reliability and safety of UAVs largely depend on the timely diagnosis of faults, particularly in the propellers, which constitute a critical part of the propulsion system and, as the most exposed structural component of the aircraft, are especially prone to faults caused by mechanical stresses or collisions with obstacles. Particular emphasis is placed on distinguishing between cases where the UAV is affected by external disturbances, such as wind gusts or load variations, and those involving an actual fault in the propeller, in order to avoid false alarms and prevent unnecessary maintenance and control actions. This necessity highlights the importance of developing a robust and reliable fault diagnosis methodology, capable of operating effectively in real-world conditions where environmental fluctuations are frequent and unpredictable. The experimental procedure involves attaching a triaxial accelerometer to a commercial DJI Mavic 3 Classic quadcopter and collecting data while the UAV performs hovering (neutral state) and hovering under varying operating conditions: 3 wind speeds and 4 lift loads. The same operating conditions are tested for 3 realistic structural damage scenarios on the front-left propeller of the UAV, involving tip breakage, tip wear, and bending of the propeller. For fault detection, the root mean square RMS is used alongside 4 machine learning methods: U-MM-PSD, U-MM-AR, U-PCA-MM-AR, and U-MM-ARMA. These methods are based on creating a Multiple-Model subspace representing the healthy flight dynamics of the UAV. They utilize features either from the Welch power spectral density (PSD) or from parameter vectors of autoregressive (AR) and autoregressive-moving-average (ARMA) models, which assume stationarity of the time series — an assumption that is not fully satisfied, while the U-PCA-MM-AR method additionally applies principal component analysis (PCA) for dimensionality reduction. For damage identification, the MM-PSD, MM-AR, and MM-ARMA methods are examined, each creating a subspace for every damage scenario. The detection and identification process is applied separately for the 3 measurement axes of the accelerometer, with the best results obtained from the axis around which the UAV performs roll rotation. The evaluation of the methods is based on hundreds of experiments, with U-MM-PSD deemed the most suitable for detection across all damage scenarios, achieving 100% successful detection for two scenarios and over 99% for the third, with less than 5% false alarms. Among the identification methods, MM-AR is considered optimal, achieving over 83% successful identification for all three damage scenarios.

Keywords

Unmanned arial vehicle, blade fault, fault detection, fault identification, machine learning methods.

INVESTIGATION OF ENERGY EFFICIENCY IN MANUFACTURING PROCESSSES: THE LASER MATERIAL REMOVAL CASE STUDY

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ABSTRACT

Within the last decades, the continuously rising energy and resource costs, as well as the newly established energy-related regulations in the industrial sector, have increased the concern for the environmental impact of manufacturing equipment. Both industry and academia are striving to find new opportunities and methods towards sustainability, considering the entire product development process. Thus, the assessment of the environmental implications of discrete manufacturing processes shows significant potential. In this thesis, energy efficiency in laser based processes is being investigated through a CO2 laser cutting case study applied to S304 stainless steel. The proposed approach is based on the use of a simulation model relying on Enthalpy Method-Based finite differences. Initially, the model is being validated using data from literature. Then, the impact of the focal plane on the achieved cutting depth is being evaluated, limiting the parameters of the investigation to laser power and cutting speed. The analysis is being conducted using two separate investigations, aiming at the observation of the energy demand in response to variations in cutting speed, laser power, and material thickness. In the first simulation series, the sheet metal thickness is constant, while the cutting speed and laser power varies to assess their impact on energy efficiency. The second series focus on varying material thickness for a given set laser power and cutting speed values, highlighting how energy demand shifts with changes in material volume and surface area. The evaluation has been based on the use of two indicators, the Linear Energy Efficiency and the Surface Energy Efficiency. Based on the collected results, Linear Energy Efficiency is a valuable metric for estimating the operational performance of the process, while Surface Energy Efficiency gives a more detailed understanding of the material's thermal behavior and possible heat-affected zones. Combined, these metrics provide a comprehensive overview of the process performance, thus facilitating the selection of optimal parameters based on material thickness.

Keywords

Laser-based processes, Laser cutting, Energy efficiency, Finite Differences Method, Modelling

DED-LB/w PROCESS OPTIMIZATION BASED ON A IN-SITU VISION-BASED MONITORING SYSTEM

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ABSTRACT

The DED-LB process is a new technology in the manufacturing world, able to repair and create different structures from scratch. This process can be found using two different types of material as feedstock, powder and wire. The latter choice offers greater quality results with less defects than the powder and is almost five times cheaper. However, due to the immaturity of the DED-LB/w process, there is the need for experts in order to use these DED machines. Currently, there are very few solutions on the market concerning monitoring and controlling the process and are mainly tailored for powder systems. The current work presents one machine learning model and one controller that are able to identify instances of satellite and stubbing defects as also quantify the heat accumulation that is built within the structure during the process. The sensing element that has been used is a vision camera. The reason of selecting this type of sensor is the initial cost, the ease it provides for integration and the amount of information it offers. Since the system is co-axially fed, the sensor is attached off-axis. For the experimental design, three different geometrical structures were used (single lines, cylinders and coupons) in order to create correlations that apply to all types of geometries. Additionally, a thermal camera has been utilized to acquire thermal data from the process and compare them with the vision ones. The vision signals are processed using image processing algorithms, and different features are extracted with the main one being the melt pool area. This feature, along with some more, have been used for the machine learning model training as also for the extraction of the correlation between the vision signals and thermal phenomena and the manufacturing thresholds. Finally, the developed controller was able to use the melt pool area feature as input and the optimal manufacturing threshold as target, and make corrections on the laser power level to create and keep a stable process.

Keywords

Additive manufacturing, Vision system, Optimization, Defects, DED

VALUE-DRIVEN DECISION-MAKING PROCESS BASED ON SYSMLV2 FOR APPLICATION TO AN AERONAUTICAL CASE STUDY

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ABSTRACT

The latching mechanism of a Lower Deck Cargo Door (LDCD) of an aircraft is considered one of the most crucial and important systems that compose the overall structure of a cargo door. The main function of such a mechanism is to keep the LDCD in a closed and locked position throughout the flight and in an open and locked position when required.

The identification of a latching mechanism, among others, as the optimum alternative requires the implementation of a well-structured decision-making process, balancing multiple attributes. Particularly, in the current thesis, a comparative analysis is carried out among three already developed latching mechanisms: Hook Spool Latching Mechanism (HSLM), Bar Latch Mechanism (BLM) and C-Latch Mechanism (CLM). Each architectural design is evaluated by seven different Key Performance Indicators (KPIs) which are derived from four specific domains: Sustainability Domain, Reliability Domain, Performance Domain and Supply Chain Domain. By applying the Multi Attribute Utility Theory (MAUT), trade-off analyses and decision-making are performed.

By implementing the outlined methodology for the estimation of the considered KPIs, it is observed that the first architectural design (HSLM) is the most reliable and sustainable. The CLM stands out for the lowest mass whereas, the BLM demonstrates the best supply chain performance. Furthermore, according to the reference case study (equal weights and linear utility functions have been assigned to all KPIs), some of the resulting alternatives are being identified as the optimum solutions (6 in total), as they combine relatively high value and low overall cost. Nevertheless, when some of the indicators are prioritised, those optimum solutions may be changed as is demonstrated in other examined case studies. This underlines the importance of contextual decision-making, where trade-offs must be carefully evaluated based on the demands and constraints of the particular research.

Generally, the identification and evaluation of judicious trade-offs among various attributes assist in improving the overall reliability and effectiveness of the latching system. The present framework has been developed for a latching system of a cargo door, however with some modifications, it can easily be adopted by other aeronautical or non-aeronautical systems.

Keywords

Latching mechanism, MAUT, Sustainability, Trade-Off Analyses, Decision-Making

REPAIRING OR PRIMARY MANUFACTURING? A COMPERATIVE STUDY ON THE ENERGY EFFICIENCY

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ABSTRACT

This diploma thesis explores a comparative study of energy efficiency between the repair of components using Additive-Subtractive Hybrid Manufacturing (ASHM) and the fabrication of new parts from scratch. The research focuses on evaluating energy consumption at each stage of the hybrid process to determine which option is more energy-efficient.

An energy efficiency calculation model was developed and implemented through an Excel-based tool. The model incorporates mathematical equations to estimate energy consumption across different stages: setup, additive, subtractive, tool exchange, and post-processing. The results take into account critical parameters such as layer height and width, laser beam intensity, cutting tool geometry, and material removal rate.

The findings revealed that, in most cases, repairing components is significantly more energy-efficient than manufacturing new ones. The hybrid method enables selective material deposition and removal only at the necessary areas, thereby reducing both raw material usage and overall energy consumption.

The study concludes that ASHM is a highly promising technology for the repair of high-value components, contributing to the reduction of the environmental footprint of industrial production.

Keywords

Energy efficiency, Hybrid manufacturing, Decision support, Subtractive manufacturing, Repair

PREDICTION OF REMAINING USEFUL LIFE OF LITHIUM BATTERIES BASED ON DISCHARGE VOLTAGE SIMILARITY

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ABSTRACT

The present study focuses on the problem of predicting the Remaining Useful Life (RUL) of lithium-ion batteries using the Discharge Potential Similarity method, relying exclusively on experimental data from full discharge cycles. Specifically, the research is based on NASA experiments involving four nominally identical batteries, each subjected to multiple operational cycles until their capacity was reduced by 30%—that is, from 2 Ahr to 1.4 Ahr—under constant discharge current of 2 A, constant ambient temperature of 24 °C, and a common discharge voltage limit of 2.7 V. The methodology is based on the analysis of discharge voltage and internal temperature curves to model the dynamic behavior of batteries under various aging conditions. Initially, by applying the Discharge Potential Similarity method combined with the Euclidean distance and using historical discharge voltage data from nominally identical batteries, the RUL is predicted. The process is then repeated, this time incorporating historical internal temperature data from nominally identical batteries into the training phase. Subsequently, the number of batteries included in the training phase is gradually increased—from one to three nominally identical batteries— in order to analyze the sensitivity of the Discharge Potential Similarity method. The results of the study demonstrated that the accuracy of capacity estimation is not necessarily aligned with the accuracy of RUL predictions, as the number of executed life cycles is not similar across all batteries. Specifically, the highest prediction accuracy for RUL is achieved when the training phase includes historical discharge voltage data from a single nominally identical battery (with a deviation between actual and predicted values of 8 cycles). In contrast, the inclusion of the temperature profile from a nominally identical battery leads to incorrect prediction of the regeneration cycles (with a deviation of 10 cycles between actual and predicted values).

Keywords

Lithium – ion batteries, Remaining Useful Life Estimation, State of Health estimation, Discharge Voltage Similarity, Euclidean distance

DIGITAL TWIN FOR ADAPTIVE CONTROL OF A FLEXIBLE MANUFACTURING CELL

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ABSTRACT

As technology is evolving, newer and more advanced tools allow for the construction of more productive yet complex systems. Modern customers seek personalized products, creating a demand for highly flexible production. In an attempt for consumer products to become more competitive, it is necessary to reduce their costs. This means that fast and accurate decision-making is needed to avoid the production of defective products. This work presents a Digital Twin of a Hybrid Manufacturing Cell which utilizes near real-time data and Artificial Intelligence to speed up the decision-making process of whether a product is defective before its production is complete. A real use case will be analyzed to determine the feasibility of automating adaptive control in this manner.

Keywords

Manufacturing Systems, Flexibility, Digital Twin, Artificial Intelligence, Adaptive Control, Decision-making, Hybrid Manufacturing

CONTRIBUTION TO AN ENGINEERING FOR SUSTAINABILITY APPROACH FOR AIRCRAFT CONCEPTUAL DESIGN ASSESSMENT

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ABSTRACT

The aviation industry faces increasing pressure to align with global sustainability goals, demanding a paradigm shift in how aircraft are conceptualized and evaluated. This thesis contributes to the development of an Engineering for Sustainability approach tailored to aircraft conceptual design by integrating sustainability and more specifically circular economy (CE) principles into early-stage assessment. The primary objective is to evaluate the CE potential of innovative aircraft configurations at the design stage, without altering the underlying designs, using relevant indicators. The research begins by identifying sustainability indicators from aviation literature, categorized across five pillars: performance, environment, cost, society, and circular economy and identifying the gap in CE assessment. A set of circularity indicators, aligned with ISO 59004 and structured under 13 Resource Management Actions (RMAs), is then selected and adapted for application at the aircraft level. Three aircraft configurations are assessed in a comparative case study: a conventional turbofan powered by fossil fuel (D250-TF-FF-2040), a turbofan using synthetic fuel (D250-TF-SF-2040), and a Mild Hybrid Electric Propulsion aircraft powered by liquid hydrogen (D250-TFLH2-MHEP-2040). Data for these indicators were extracted and processed from CPACS files, using specialized tools like RCE, enabling structured indicator integration and visualization, and from literature. Through a multi-scenario evaluation approach, incorporating equal, design-focused, and end-of-life-focused weighting strategies, the thesis demonstrates how circularity indicators can provide valuable insights into sustainable aircraft design trade-offs. Results show consistent performance rankings, with the MHEP-LH_2 concept achieving the highest circularity scores, validating the framework's robustness and potential application for comparative design assessments.

Keywords

Aircraft, Aviation Sustainability, Circular Economy, Assessment

DIVISION OF ENERGY, AERONAUTICS AND ENVIRONMENT (JUNE 2025)

NUMERICAL SIMULATION OF FLOW OVER A BACKWARD FACING STEP USING THE IPOT METHOD

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ABSTRACT

This thesis addresses numerical simulation of flow over a backward-facing step by the IPOT and Rhie – Chow method in two dimensions. The objective was to examine how different spatial discretization schemes (FTCS and Upwind) influence the solution, and to compare the IPOT and Rhie–Chow methods in terms of convergence, accuracy, and stability.

The problem was studied in situations of optimal stability using the appropriate stability criteria and discretization parameters. The computational domain was constructed to resemble a duct, providing a suitable environment for simulating the step geometry. Boundary and initial conditions for both pressure and velocity were appropriately defined.

When combined with the FTCS scheme, the IPOT method exhibited slow convergence; however, it produced stable solutions that were consistent with physical expectations. In contrast, the Upwind scheme failed to converge within a reasonable number of iterations for certain initial velocity values.

On the other hand, the implementation of the Rhie–Chow method significantly improved both numerical stability and convergence rate for both FTCS and Upwind schemes. This technique effectively eliminated the minor oscillations observed in the standard IPOT approach, resulting in a stable solution.

The simulated results clearly depict the pressure and velocity fields at key time steps, highlighting the superior performance of the Rhie–Chow method. Overall, it proves to be highly effective in suppressing numerical noise and accurately capturing the flow field, particularly in regions with abrupt geometric changes.

The thesis concludes with a discussion of the comparison of the results, highlighting the strength and drawbacks of both approaches, giving valuable insights for future application to flow problems involving sudden changes in geometry.

Keywords

IPOT method, Rhie – Chow method, FTCS/Upwind scheme, Backward-facing step, Computational Fluid Dynamics

NUMERICAL SIMULATION OF THE AIR FLOW FIELD FROM LINEAR GRILLES WITH REGULATING DUMPER IN DIFFERENT POSITIONS UP-MIDDLE-DOWN AND VARIOUS TEMPERATURE DIFFERENCES OF THE SUPPLIED AIR

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ABSTRACT

This thesis focuses on the study of air flow through a grille in an enclosed space with predefined dimensions, aiming to determine and evaluate the main flow characteristics. These include velocity distribution, pressure drop, throw, rise, and diffusion of the air jet. The maximum allowable airflow was defined based on the critical outlet velocity from the grille, set at 10 m/s. The region of interest, corresponding to the occupant zone under thermal comfort conditions, is defined by an air velocity of 0.5 m/s. The Realizable k-ε turbulence model was used for the prediction of the flow field. Additionally, the numerical solution algorithms, discretization methods, and turbulence modeling approaches are presented. A grille with an adjustable damper was tested in upper, lower and middle positions and for different temperature differences of the supply air. The grille was designed in SOLIDWORKS, while the computational analysis and visualization of the results were performed using ANSYS Fluent. The analysis revealed that the grille position significantly affects the airflow pattern and thermal comfort in the room. The middle damper configuration provided the most favorable flow distribution, maintaining low air velocities in the occupant zone and ensuring thermal comfort. Temperature variations mainly influenced pressure drop and diffusion. The results offer valuable insights for the optimal design of ventilation systems, reducing experimental time and cost.

Keywords

Grilles, air beam, comfort, finite elements, computational fluid dynamics

COMPUTATIONAL ANALYSIS OF AIR FLOW FROM AIR-CONDITIONING GRILLES OF SLOT TYPE WITH REGULATING DAMPER OF THE FLOW DIRECTION FOR DIFFERENT TURBULENCE MODELS

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ABSTRACT

This thesis focuses on the computational analysis of airflow behavior through three variations of the STS 2R air grille, each featuring a different effective outlet area. The study was conducted using ANSYS Fluent, primarily applying the realizable k–ε turbulence model, while the k–ω SST model was also employed for comparison in one configuration. The geometry was created in SolidWorks, replicating the experimental test room of the Laboratory of Fluid Mechanics at the University of Patras. Airflow simulations were performed across a wide range of flow rates, from 100 to 1700 m^3/h, with the upper limit determined by the maximum acceptable outlet velocity.

For each case, key parameters such as pressure drop, throw distance, spread, rise, drop of the jet, and noise level were calculated and evaluated. Visual results (contours) and graphs were used to illustrate the trends and differences between configurations. The final assessment identifies the most efficient grille setup depending on comfort requirements and airflow performance, offering practical insights for HVAC design and selection.

Keywords

Airflow, slot-type grilles, HVAC, CFD

STUDY OF SENSITIVITY OF THE NUMERICAL SOLUTION AND ITS ERROR WITH RESPECT TO PARAMETERS OF FLOW FIELD SIMULATIONS

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ABSTRACT

This thesis investigates the sensitivity of numerical solutions and their associated numerical errors with respect to variations in key physical (flow) and numerical parameters. Working within the framework of Computational Fluid Dynamics (CFD), many state-of-the-art problems are addressed and practical solutions are proposed. The findings of this study, namely the inexpensive evaluation of a "nearby" flow field, and a novel error estimation and sensitivity analysis framework, can contribute to improving predictive capabilities in CFD by highlighting the role of parameter selection and grid design in minimizing numerical uncertainty.

A comprehensive methodology is developed to systematically assess how perturbations in arbitrary parameters affect both the numerical solution and the numerical error itself. The analysis is carried out using custom made solvers tailored to the needs of this thesis. These solvers allow the analysis to be applied to a range of established benchmark cases, that include both analytical and computed flow fields. Analytical and semi-analytical solutions serve as "proof-of-concept" tools, while more complex computed cases, such as the flow in a channel, flow over a backward-facing step, demonstrate the applicability of the proposed framework to practical CFD problems.

Keywords

numerical solutions, parametric problems, sensitivity analysis, error estimation, grid adaptation

NUMERICAL INVESTIGATION OF TOPOLOGICAL STRUCTURES AND VORTEX DYNAMICS IN TURBULENT FIRE PLUMES AND FIREWHIRLS

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ABSTRACT

Understanding the mechanisms governing the development of combustion phenomena such as buoyant flames and fire whirls has become an area of increasing research interest in recent years. These types of flames occur both in industrial applications, such as burners and combustion chambers, and in natural disaster scenarios, such as urban fires. Their behavior, which arises from the interplay between buoyancy, swirl, and diffusion, renders them particularly complex to model and predict. Comprehending the parameters that influence the dynamics of such phenomena is critical for optimizing energy efficiency, minimizing pollutant emissions, and managing hazardous situations.

This diploma thesis focuses on the numerical investigation of propane-fueled buoyant diffusion flames and fire whirls using the computational framework of Ansys Fluent. The objective is to compare the behavior of the two flame types and examine the influence of swirl, fuel supply rate, and domain geometry on flame development and flow characteristics. Simulations were conducted for three different fuel input levels — 25, 50, and 100 kW — for each of the two cases. The Reynolds Stress Model (RSM) was employed to describe turbulence, due to its capability to resolve the individual components of the Reynolds stress tensor in strongly anisotropic and swirling flows. For the combustion chemistry, the Flamelet Generated Manifold (FGM) model was selected, as it efficiently captures complex thermochemical behavior in diffusion flames with reduced computational cost. Propane combustion was modeled using a detailed chemical mechanism consisting of 45 chemical species. The results obtained from the aforementioned simulations are compared with experimental measurements of temperature and axial velocity, while, in addition, both local and global values of basic dimensionless numbers (Fr, Gr, Ri, Da) are calculated, from which valuable conclusions are drawn regarding the underlying physical differences between the

two combustion phenomena under study. The above simulations also offer the opportunity to evaluate the performance of the selected turbulence and combustion models in terms of their accuracy and their capacity to simulate complex combustion phenomena such as buoyant diffusion flames and fire whirls.

Keywords

Propane Combustion, Buoyant Flame, Fire Whirl, Reynolds Stress Model (RSM), Flamelet Generated Manifold (FGM), Dimensionless Numbers

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING VENTS FOR WALL OR CEILING INSTALLATION WITH GRILLES OF SLOT TYPE WITH REGULATING DAMPER OF THE FLOW DIRECTION FOR DIFFERENT TURBULENCE MODELS AND DIFFERENT TEMPERATURES

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ABSTRACT

The aim of this thesis is to examine the air flow exiting a grille in a room of predetermined dimensions. This study is carried out by calculating and evaluating the characteristic flow parameters: velocity distribution, pressure drop, rise, drop, throw, and spread. The values are calculated using computational fluid dynamics with the ANSYS Fluent program, while the grille was designed using SOLIDWORKS. The grille studied is able to adjust the initial direction of the air stream through adjustable fins, so the calculations were performed for three cases of the initial direction: upward, horizontal, and downward. A comparative analysis was also carried out for two turbulence models used for the simulation, k-epsilon and k-omega, as well as for an exiting air temperature equal to the room temperature, 5 degrees lower and 5 degrees higher. The upper limit of the exiting air flow from the grille was determined based on the maximum permissible speed of 10 m/s. The area of interest of the study was defined with the air velocity limited to 0.5 m/s, where comfort conditions prevail for those seated in the studied space.

Keywords

Grilles, Air Flow, Comfort, Finite Elements, Computational Fluid Dynamics, Turbulence Models.

COMPUTATIONAL SIMULATION OF A DOUBLE-PIPE HEAT EXCHANGER WITH INTERNAL GROOVES

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ABSTRACT

This study presents a comparative evaluation of the performance of a smooth tube versus an internally-grooved (enhanced) tube, using the Nusselt number and the friction factor as the principal metrics. The influence of internal grooves on heat-transfer capability—and the accompanying pressure losses—was assessed through both theoretical correlations and detailed numerical simulations.

The results show that the grooved tube delivers a markedly higher heat-transfer rate, with the Nusselt number rising significantly relative to the smooth tube. This gain becomes even more pronounced as the Reynolds number increases, owing to the stronger turbulence and intensified fluid mixing induced by the groove geometry. At high Reynolds numbers, the thermal performance of the enhanced tube is nearly twice that of the conventional smooth tube.

This thermal improvement is accompanied by an expected rise in the friction factor and therefore by higher pumping-power requirements. Although the friction factor decreases with increasing Reynolds number, the grooved tube consistently exhibits larger values than its smooth counterpart. Overall, the work demonstrates that internal grooves constitute an effective passive technique for augmenting forced-convection heat transfer, albeit at the cost of greater hydraulic resistance. Future research should explore a wider range of groove geometries, account for temperature-dependent fluid properties under realistic operating conditions, and test alternative turbulence models. Expanding the experimental database to broader ranges of temperatures and flow-rates will further strengthen the accuracy and generality of the conclusions.

Keywords

heat exchangers, grooved tubes, Nusselt number, friction factor, heat transfer, turbulent flow, computational fluid dynamics (CFD), thermal performance

EXPERIMENTAL INVESTIGATION OF THE AERODYNAMIC BEHAVIOR OF A LIFTING SURFACE WITH ACTIVE CAVITIES

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ABSTRACT

This diploma thesis focuses on the theoretical and experimental investigation of using surface dimples on the upper side of a wing as a passive flow control method aimed at improving aerodynamic performance. Initially, a comprehensive theoretical framework is developed to explain the mechanisms by which dimples influence airflow and delay boundary layer separation. At the same time, the geometric parameters of the dimples are examined, along with their contribution to changes in aerodynamic behavior. Key design criteria, based on literature data, are presented to guide the rational configuration of dimples under different flow conditions. Building on this theoretical foundation, a novel dimple configuration is proposed and implemented on a test wing, which is experimentally studied under wind tunnel conditions. The setup includes an innovative mechanism for adjusting the dimple depth, allowing for geometry modification without replacing the physical model. To assess the aerodynamic performance of the dimpled wing, a calibration methodology is employed using machine learning tools to refine the experimental results. Finally, the experimental findings are presented and analyzed, with the aim of evaluating the effectiveness of the method, comparing different configurations, and investigating the contribution of dimples to aerodynamic optimization.

Keywords

Dimples, Boundary layer separation, Flow control, Aerodynamic characteristics, Airfoil

NUMERICAL EXPLORATION OF TERRAIN-INDUCED ANISOTROPIC VORTICITY AND FLAME-FLOW INTERACTIONS IN INCLINED FIRE PLUME AND FIRE WHIRL

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ABSTRACT

The phenomena of fire plume and fire whirl have been extensively studied by the combustion research community due to their critical role in understanding the dynamics of large-scale fires. A fire plume refers to a free, vertical flame where fuel and oxidizer meet and gradually mix through diffusion without prior premixing. In contrast, a fire whirl is a highly dangerous phenomenon characterized by a vertically rising column of flame and combustion gases that rotate around their axis, exhibiting increased height, elevated temperature, and reduced turbulence intensity in the vortex core under intense combustion and swirling flow conditions.

This study focuses on the numerical exploration of terrain-induced anisotropic vorticity and flame-flow interactions in fire plume and fire whirl, under the influence of three different ground inclination angles (0°,5°,10°). The simulations were conducted using the k-ω SST turbulence model combined with the Flamelet Generated Manifold (FGM) model within the Partially Premixed Combustion framework. All computations were performed using the commercial software ANSYS Fluent.

Initially, baseline simulations were carried out for both phenomena without terrain inclination. The objective was to validate the numerical models and assumptions by comparing the computational results with relevant experimental data from literature. The simulations showed good agreement with the experimental observations and confirmed the expected behavior of fire whirls: greater flame height, higher velocities and temperatures, and a narrower, more stable structure compared to fire plumes.

Subsequently, simulations including ground inclination were conducted to explore the influence of geometry on the flow and thermal fields. The analysis placed particular emphasis on four characteristic dimensionless numbers: Damkohler, Grashof, Froude and Richardson, which provided critical insight into the flow regimes and dominant physical mechanisms. The results indicate that increasing the ground slope enhances buoyancy-driven forces over the inertial forces, leading to a transition toward flow regimes with stronger natural convection characteristics.

In conclusion, this study demonstrates the effectiveness of numerical tools in capturing complex combustion phenomena and contributes to a deeper understanding of the mechanisms governing the evolution of fire whirls in geometrically realistic environments.

Keywords

Numerical Simulation, Fire Plume, Fire Whirl, Anisotropic Vorticity, Slope Effect, Dimensionless Numbers

DEVELOPMENT MODEL ON SIMULINK SIMULATING A PUMPING STATION

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ABSTRACT

This thesis focuses on the development of simulation models using Simulink to compare different pump configurations in a pumping station. Initially, a theoretical overview of pump types (positive displacement and dynamic pumps) is presented, along with their operating characteristics, including performance curves (flow rate vs. head, efficiency, and power).

Special attention is given to the concept of the operating point, the consequences of operating away from the Best Efficiency Point (BEP), and the phenomenon of cavitation, with emphasis on the NPSH parameter and the conditions that cause it. Subsequently, two main pump connection methods (series and parallel) are analysed in terms of hydraulic behaviour, system performance, and design requirements.

Simulation models for three configurations (single pump, pumps in series, and pumps in parallel) are implemented in Simulink. Through simulation results and characteristic curves, the performance of each configuration is evaluated based on energy efficiency, flow rate and operational stability.

The thesis concludes with key observations for selecting the optimal connection strategy based on system demands, highlighting the role of Simulink as a valuable tool for designing and analysing pumping systems.

Keywords

Pumps, series and parallel connection, operating point, cavitation, simulation, simulink

ENERGY EFFICIENT BUILDINGS: OPTIMIZATION METHODS OF MODELS SIMULATING THE BUILDINGS ENERGY PERFORMANCE

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ABSTRACT

There is no doubt about the critical role of building energy consumption in the global energy crisis, the building sector accounts for 40% of global energy use and roughly 37% of greenhouse gas emissions. Addressing the environmental implications of this issue as well as working towards greener, more energy efficient buildings will prove critical in the coming years. One such method of mitigating the ever-increasing rising energy consumption of buildings is optimizing the design of the structure during construction or renovation. Two main categories of optimization methods are widely utilized, simulation-based methods and machine learning surrogate models. Applying the principles and the aforementioned models of optimization requires the decision makers to follow a series of steps, namely choosing the objectives during the design phase, these are called objective functions and include metrics such as the yearly energy consumption and life cycle cost of a structure. Choosing the design variables for optimization is equally as important, common variable choices among decision makers include the envelope's elements, geometry and HVAC system parameters. In this work the choice was made to optimize the design phase of a residential building by undertaking a multi-objective optimization case study, specifically minimizing two objective functions, the material costs and the thermal energy needs of the building. To achieve this, two computational tools were developed in the frame of this work and utilized in the optimization process. The first is a MATLAB script source code and the second is a supplementary Excel spreadsheet from which any user can change any parameter they want, making them adaptable to any problem. The quality of the search area coverage along with the general depth of the analysis of the optimization problem hinges on the sound choice of three hyperparameters, the maximum number of generations, the population size of each generation and the mutation rate of the algorithm.

Keywords

Energy Efficient Buildings, Multi-Objective Optimization, Design Variables, Objective Functions, Hyperparameters

COMPUTATIONAL SIMULATION OF AIR CONDITIONING FLOW FIELD FROM SWIRLING CEILING GRILLES OF SQUARE OR CIRCULAR FRAME AND VANES IN RADIAL ARRANGEMENT OF CIRCULAR CONFIGURATION FOR DIFFERENT TEMPERATURES

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ABSTRACT

The purpose of this thesis is to analyze the airflow from grilles in a reference room in order to calculate their characteristic dimensions and evaluate the impact of the grilles on the airflow for potential users. Additionally, the difference in flow caused by variations in room temperature will also be studied. The dimensions considered in this study include pressure drop (ΔP),throw, fluid spread in the XY and YZ planes, noise (dB), and velocity distribution (m/s). Specifically, two velocities of interest are the maximum exit velocity of the air from the grille, which we will study and is equal to Vc = 10 m/s, and the air velocity that will provide the expected comfort conditions within the room, which we have defined as equal to 0.5 m/s. The grilles for the study were designed in SOLIDWORKS, and the flow was analyzed in ANSYS Fluent using the Realizable k-epsilon turbulence model. The results of the analysis will be presented and discussed in tables that highlight how each parameter develops within the room, as well as in comparative diagrams between grilles for these parameters.

Keywords

Grilles, Temperature, Computational Fluid Dynamics, Finite Elements

EXPERIMENTAL STUDY OF AN INTERNAL TURBULENT FLOW AND EVALUATION-CONFIRMATION WITH THE COMPUTATIONAL TOOL SIMULINK (MATLAB)

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ABSTRACT

This thesis focuses on the study of airflow in a duct network, with the main objective being the investigation of pressure losses and the development of the velocity profile from the air's entry into the system until the flow becomes fully developed. Such losses, directly linked to energy consumption, depend on the geometry of the network, the presence of branches, valves, and frictional effects. Understanding these parameters is essential for optimizing ventilation, HVAC systems, and industrial fluid transport.

To explore these phenomena, a dedicated experimental setup was designed and constructed. It consists of a straight duct with two branches and adjustable valves. Differential pressure sensors and Prandtl tubes were used to measure pressure drops and local flow velocities under different flow configurations. These measurements provided insight into how geometric changes and valve positions influence energy losses and the development of the flow profile from the duct inlet to the fully developed region.

In parallel, a simulation model of the setup was built using MATLAB Simscape to replicate the experiment. The comparison between experimental and numerical results served as a cross-validation method, enhancing the reliability of the findings and providing a more comprehensive understanding of the system's behavior.

Overall, this study aims to deepen the understanding of internal airflow mechanics in ducted systems, bridging practical measurements with simulation tools. The work highlights the importance of combining hands-on experimentation with computational modeling in fluid dynamics education and in the design and analysis of efficient ducted flow systems. At the same time, the experimental results confirm existing theoretical models that describe pressure losses and flow development in ducted systems.

The structure of this thesis is organized into five main chapters. The first chapter presents the introduction and the overall context of the problem. The second chapter covers the theoretical background, including the principles of flow in pipelines, pressure losses, and the development of the velocity profile. The third chapter provides a detailed description of the experimental setup, the measurement instruments, and the data acquisition methodology. The fourth chapter focuses on the numerical simulation of the system using the Simscape environment in MATLAB. Finally, the fifth chapter presents the analysis and comparison of the experimental and computational results, along with the main conclusions drawn from the study.

Keywords

Airflow, Pressure losses, Flow development, Experimental analysis, Simulation

ENERGY ANALYSIS AND MODELING OF DAIRY INDUSTRIES

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ABSTRACT

This diploma thesis deals with the integration of machine learning techniques in the field of energy audits, aiming at a more effective approach to baseline energy consumption in industrial environments. Initially, the theoretical basis of energy audits is presented and a literature review of the relevant international and domestic practice is carried out. This is followed by the description of four dairy industries that constituted the subject of study, using their consumption data for the evaluation and creation of baselines. The main part of the thesis follows, where a computational tool was developed in the MATLAB environment, with the help of the Regression Learner application, which is used for the construction of baselines, in order to be compared with the conventional linear regression currently applied in Greece. The computational tool develops four basic regression models: Linear Regression, SVM Regression, Neural Network Regression, and Gaussian Process Regression, and is evaluated in the same way as the conventional linear regression method, mainly with the RMSE and R^2 errors. A key advantage of the machine learning models was the use of Cross-Validation, which leads to more reliable results and better predictive ability for post-evaluation energy consumption forecasts. During the evaluation of the tool, it was found that the Linear and Gaussian models performed better, while Neural Networks and SVMs require several improvements. In addition, it was proven that the tool functions equally effectively for both one-year and two-year energy consumption data, as well as for a small or large number of variables. The application of the procedure to the four industries showed that, in all cases, the machine learning models provided more accurate predictions than conventional linear regression. In conclusion, the thesis demonstrates that machine learning methods can constitute a powerful alternative tool for the estimation of energy consumption, offering greater accuracy, predictability, and adaptability compared to classical statistical approaches.

Keywords

Energy audit, energy baseline, machine learning

ENERGY SAVING IN THE BUILDINGS SECTOR: BUILDINGS SKIN AND ENERGY SYSTEMS

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ABSTRACT

This thesis addresses the enhancement of building energy performance through strategic interventions in the building envelope and energy systems. The theoretical part presents key concepts such as the roles and characteristics of the building envelope, the urban heat island effect, the properties of next-generation glazing, the concept of thermal comfort, and the benefits of green roofs for building thermal behavior and microclimate regulation.

Initially, the study analyzes the significance of the building envelope as a key factor in energy efficiency, with an emphasis on thermal insulation, moisture protection, airtightness, and acoustic performance. It discusses current trends and innovations that improve energy consumption, and thoroughly examines modern types of glazing and their thermophysical properties, which significantly influence energy performance and indoor thermal comfort. Special attention is given to factors affecting thermal comfort, such as temperature, humidity, radiation, and air movement, along with various energy systems that can be integrated to further improve performance.

The following section analyzes the building in its current state, without any energy retrofit interventions, serving as a baseline for comparison. Key characteristics of the building are presented, including its dimensions, climatic zone, and details about the walls and roof. The case study concerns an apartment on the first floor of a multi-storey residential building constructed in 1985 in the city of Agrinio. As the building permit was issued in 1984, after the implementation of the Greek Building Thermal Insulation Regulation (1979), the building includes partial thermal insulation on exterior walls and the roof. The building is evaluated using both the TEE-KENAK software and a degree-day method tool for calculating energy parameters.

Subsequently, seven energy retrofit scenarios are studied, involving targeted interventions to reduce energy consumption and CO_2 emissions. The first scenario involves the installation of

an extensive green roof on the existing uninsulated roof, using a pumice-grass mixture. The second scenario examines the same roof with an intensive green roof using a peat-pumice mixture and lavender planting. The third scenario includes the application of external thermal insulation to improve the building's envelope.

The fourth, fifth, and sixth scenarios involve the upgrading of glazing, replacing existing windows with double glazing, double Low-E glazing, and triple glazing with argon gas, respectively—each differing in composition and insulation characteristics. Finally, the seventh scenario combines the intensive green roof, external insulation, and triple glazing, as these were the most effective in reducing the building’s energy consumption.

The comparison between the two software tools shows that, despite minor discrepancies, the degree-day method demonstrates energy performance trends similar to TEE-KENAK, supporting its reliability and applicability for future use.

The analysis results show a progressive reduction in energy consumption and CO_2 emissions with each intervention. The implementation of green roofs in the first two scenarios contributes to energy savings and improved thermal comfort, while the application of external insulation and glazing upgrades lead to further reductions. In the combined scenario, energy consumption is reduced by 66% and CO_2 emissions by 34.4%, resulting in an energy class upgrade from E to C.

Overall, the study highlights the importance of a holistic approach to building energy retrofitting, with particular emphasis on glazing upgrades and green roof adoption—factors that significantly contribute to energy savings and CO_2 emission reduction, promoting sustainability in the urban environment.

Keywords

Energy Consumption, Glazing, Sustainability, Green Roofs, CO_2 Emissions

ENERGY EFFICIENCY STUDY OF A SMALL HYDROELECTRIC POWER PLANT - CASE STYDY OF GLAFKOS

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ABSTRACT

This Thesis was conducted within the framework of the Laboratory of Fluid Mechanics and Its Applications. Its subject concerns the study of the performance of the Glafkos Small Hydroelectric Project (S.H.P.). Firstly, an extensive reference is made to Small Hydroelectric Projects (S.H.P.). Subsequently, special mention is given to the Glafkos S.H.P., which is the main object of our study. Then, the fundamental components of the project are described, including the spillway, the arched gate, the automatic counterweight gate, the intake tunnel, the surge tank, the penstock, the power plant, the central control unit, as well as the types and number of hydro turbines used.

Following this, emphasis is placed on presenting a major subject of Fluid Mechanics, that of hydro turbines. Special reference is made to the three main types of hydro turbines: Pelton, Francis, and Kaplan. Their characteristic parameters are described, with particular focus on the phenomenon of cavitation. Next, the selection process for the type and number of hydro turbines in a hydroelectric system is presented. After establishing the theoretical background of the Thesis, the necessary research is conducted to draw conclusions regarding the study and calculation of fundamental parameters related to the performance of the Glafkos S.H.P. Specifically, using both analytical calculations and the Canadian software RETScreen, we constructed the duration curves for this S.H.P. for the years 2014 and 2015 and calculated the total amount of energy produced each year.

More specifically, our objective for each year was to compare the estimated energy production obtained through analytical calculations, based on the specifications, with the energy production values calculated from the scenarios we simulated using the RETScreen software. The two scenarios examined were: in the first case, only the Francis turbine with a capacity of 2.29 MW was operating, while in the second case, only the two Pelton turbines with a capacity of 1.4 MW each were operating at the Glafkos S.H.P. Finally, to complete the study of this S.H.P., a techno-economic analysis was conducted. More specifically, using the RETScreen software, we described the calculation of all expenses, ultimately determining the total cost of the investment under study.

Keywords

Energy Efficiency, Glafkos S.H.P. (Small Hydroelectric Project), Hydro Turbines, RETScreen, Duration Curves

DIVISION OF MANAGEMENT AND ORGANIZATION STUDIES (JUNE 2025)

PROJECT MANAGEMENT OF INDUSTRIAL BUILDING CONSTRUCTION WITH PRECAST CONCRETE ELEMENTS USING MICROSOFT PROJECT

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ABSTRACT

This thesis focuses on the management of an industrial building construction project using precast concrete elements and the Microsoft Project software. The theoretical part presents the framework of modern project management, emphasizing techniques such as the Critical Path Method (CPM), performance indicators (EV, SV, CV), and risk analysis. It also explores off-site construction and the use of precast concrete components, which are manufactured under controlled conditions and offer significant advantages for projects with strict timelines.

In the practical part, the project was simulated within the Microsoft Project environment, with detailed recording of the work structure, resource management, and periodic progress reviews. During project execution, deviations in time and cost were identified, necessitating a rescheduling process. In this context, four alternative mitigation strategies were analyzed and evaluated:

(a) the Fast Tracking technique, which involves overlapping activities to shorten the overall project duration,

(b) the combination of Fast Tracking & Resource Leveling, aiming simultaneously at time reduction and resource optimization,

(c) the use of precast concrete elements to accelerate the project through off-site construction,

(d) and the hybrid solution, which combines the benefits of precast construction, fast tracking and resource management for optimal time and cost performance.

From the comparative evaluation of five rescheduling scenarios, it was found that the "no action" scenario (A) leads to financial loss, whereas the hybrid scenario (E), combining precast elements with resource management, offers the most balanced solution. Thus, it is demonstrated that the use of precast systems and the effective application of project management tools can ensure the timely and financially sustainable completion of complex construction projects.

Keywords

Project Management, Precast Concrete Elements, Project Scheduling, Microsoft Project, Resource and Cost Optimization

PROJECT MANAGEMENT AND SCHEDULING TECHNIQUES: A CASE STUDY ON A LANDING GEAR SYSTEM

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ABSTRACT

The present diploma thesis comprises a literature review of the principal project management and scheduling methods, as well as their application to a case study involving the development of an aircraft landing gear system in an industrial context. Initially, it presents a review of the historical evolution of the concept of Project Management and the techniques that have accompanied it through the centuries, offering a spherical overview of the progression that has shaped the current state of the field. The following chapter dives into the tools and techniques that are integral to today's Project Management practices, with particular emphasis on their application, supported by an in-depth presentation of the corresponding methodologies. Specifically, the current thesis clearly and concisely outlines the philosophy behind creating a Gantt Chart, as well as the theoretical foundations of the CPM/PERT methods, the Work Breakdown Structure (WBS), Earned Value Management (EVM), and Milestone Planning techniques. Chapter 3 presents the case study of an industrial project focused on the development of an aircraft landing gear system, in the analysis of which all aforementioned project management techniques were implemented. More precisely, the project was analyzed and structured at a task level utilizing the WBS structure, scheduled based on the estimated duration of its constituent tasks, and assessed using real-time data regarding time and cost performance through the Earned Value Management (EVM) approach.

The thesis concludes (Chapter 4) with a concise reflection on the utility and critical characteristics of the methods discussed, drawing meaningful conclusions regarding the effectiveness of each technique used in organizing and scheduling the said landing gear development project, and thus aiming to facilitate the selection of the appropriate method according to the needs and demands of modern industrial level projects.

Keywords

Project Management, Critical Path, Earned Value Management, Work Breakdown Structure, Aircraft Landing Gear

STRATEGIC PRODUCT PORTFOLIO MANAGEMENT IN HIGH GROWTH COMPANIES: EMPIRICAL STUDY

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ABSTRACT

This thesis examines how high-growth startups in the San Francisco Bay Area strategically manage their product portfolios. The research focuses on two main questions: (1) What are the key challenges these companies face in product portfolio management (PPM)?, and (2) What strategies do they use to make strategic decisions under conditions of rapid growth and uncertainty?

The methodology followed a qualitative approach, using a multiple case study design and semi-structured interviews with seven key decision makers from fast-growing B2B and B2C companies. Through thematic analysis, common challenges were identified, as well as the main tools and reasoning used to support decision-making.

To address these, startups adopt impact-driven and adaptive strategies rather than rigid frameworks. Key practices include prioritizing measurable customer and business outcomes, maintaining team alignment through lightweight rituals (e.g., OKRs), and applying simple prioritization mechanisms. Strategic approaches are often iterative and context-specific, shaped by leadership experience and evolving growth stages.

The study concludes that effective PPM in high-growth environments is fluid and adaptable. Rather than formal structures, outcome orientation, team coherence, and decision agility are central to scalable product strategy. These findings extend theories of dynamic capabilities, lean experimentation, and emergent strategy in early and later stage innovation contexts.

Overall, the thesis aims to bridge the gap between theory and practice, offering useful insights for startup founders, investors, and researchers involved in growth and product portfolio strategy within dynamic environments.

Keywords

High-Growth Firms, Scaling, Product Portfolio Management, Strategy, Portfolio Management

ANALYSIS OF BUSINESS ATTITUDES TOWARDS CLIMATE CHANGE FOLLOWING THE APPEARANCE OF UNEXPECTED EVENTS USING THE "EXIT-VOICE-LOYALTY" THEORY

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ABSTRACT

Climate change represents one of the most significant challenges of the modern era, drastically impacting the business environment and prompting companies to redefine their strategies with sustainability in mind. The growing pressure to comply with environmental standards—even when these are not legally binding—creates complex dilemmas that require to balance between economic interest and environmental responsibility. In this context, Albert Hirschman's "Exit, Voice, Loyalty" theory provides an analytical lens for understanding the strategic responses of businesses to non-mandatory regulations, as well as the consumer behaviors that develop in reaction to these strategies. The modes of response—exit, voice, and loyalty—are shaped by a variety of economic, institutional, and social factors. Understanding the feedback mechanisms triggered by market pressures, societal expectations, and regulatory developments reveals key variables that influence the transition of businesses toward more sustainable practices. Through this dynamic perspective, critical questions emerge regarding the strategic behavior of economic factors in environments of heightened uncertainty and shifting value systems.

Keywords

Climate change, "Exit, Voice, Loyalty" Theory, Firm, Consumer

STATISTICAL AND MACHINE LEARNING TECHNIQUES FOR RENEWABLE ENERGY GENERATION

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ABSTRACT

In recent years, the transition to more sustainable sources of electricity energy generation has become one of the most significant goals of the scientific community. The impacts of climate change and the rising levels of carbon dioxide emissions ($CO2$), along with other deleterious pollutants, make the transition to sustainable energy sources one of the most urgent objectives for the scientific community. In that context, Renewable Energy Sources (RES), such as solar energy, play a vital role.

The Sun is estimated to be active for another 5 billion years, thus being a considerable inexhaustible energy source. On that account, solar energy is one of the most widespread forms of renewable energy, offering quite significant benefits in comparison with other RES. Additionally, electricity generated through solar energy has an extremely low environmental impact, as it produces zero harmful pollutants during the production process. Consequently, solar energy is a key pillar for achieving sustainable development objectives and energy transition.

Forecasting the electric energy generated from solar energy is not only a critical challenge, but also a necessity to optimize the use of solar energy in energy infrastructure. Therefore, the current thesis examines the prediction of future electric energy generated from photovoltaic systems production prices in Greece.

The analysis is carried out through the benchmarking of three different types of forecasting models. The models considered include the ARIMA statistical model as well as two state-of-the-art machine learning and deep learning algorithms: the XGBoost model and the LSTM neural network. The models were selected based on their capability to process data sequences and complex time series. Ultimately, their comparison aims to identify the most sufficient model for the specific issue, considering the distinctive features of the analyzed dataset. Based on the examined error metrics (RMSE and nRMSE), the LSTM network and the ARIMA model

demonstrated the best performance in medium-term forecasting, on the grounds that these models yield the lowest values in these metrics. In contrast, the XGBoost algorithm produced the highest error values, indicating the least forecasting accuracy in the context of the present application.

Keywords

RES, Energy generation forecasting, Solar energy, Artificial Intelligence, ARIMA, LSTM, XGBOOST

PROJECT MANAGEMENT OF LARGE IFRASTRUCTURES IN GREECE AND INTERNATIONAL GOOD PRACTICES

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ABSTRACT

This thesis was motivated by the chronic inefficiencies and systemic obstacles in the management of large public infrastructure projects in Greece. Despite the country's significant investment in transport, energy, and urban development, major projects have often suffered from delays, cost overruns, fragmented responsibilities, and weak stakeholder coordination. These recurring issues raised a critical question: *Can international project management methodologies be effectively adapted to improve infrastructure governance in Greece?*

The thesis thus set out to explore the gap between Greek practices and international standards. The rationale for the research lies in the mismatch between the complexity of modern infrastructure projects and the current administrative capacity of the Greek public sector. Legal rigidity, unstable political priorities, inadequate project scoping, and lack of standardized tools have led to low efficiency and public dissatisfaction.

In response, the study undertook a systematic analysis of internationally recognized methodologies—PMBOK, PRINCE2, PM², ISO 21500, Agile and Lean. These offer structured approaches to project planning, execution, monitoring, and closure, emphasizing clarity of roles, stakeholder engagement, risk management, and value creation. The contrast with Greek practices revealed a need for reform not only at the technical level, but also at the institutional and cultural levels.

Based on this diagnosis, the thesis proposes a hybrid and phased reform strategy:

1. **Short-term (Pilot Phase)** – introduction of best practices in selected public projects.
2. **Mid-term (Institutional Phase)** – reform of legal and organizational frameworks.
3. **Long-term (Systemic Phase)** – establishment of a national project governance model aligned with European standards.

The research emphasizes that the adoption of international practices must be selective and adapted to Greece's unique administrative, geographical, and socio-political conditions. The ultimate aim is to enable the public sector to deliver large-scale projects more efficiently, transparently, and sustainably.

Keywords

Project Management, Infrastructure, Greece, Public Sector, Reform, International Standards, PMBOK, PRINCE2, PM², Agile, Lean, Institutional Change, Stakeholders, Governance, Capacity Building

DEVELOPMENT OF AN INTERGRATED MODEL OF ORGANIZATIONAL RESILIENCE TO CLIMATE CRISIS

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ABSTRACT

This research assesses the preparedness of Greek businesses to address extreme weather events. At the same time, it explores their resilience to the impacts of climate change and, through the evaluation and understanding of the strategies employed by Greek enterprises to strengthen their resilience, it aims to develop a functional model that can be adopted by organizations to enhance said resilience against the ongoing crisis and its consequences. There are many different industries that will be affected by climate change, making it one of the most pressing challenges humanity faces. Climate change has both direct and indirect effects on businesses, including economic losses and operational disruptions. Resilience — the ability of a system to adapt to, cope with, and ultimately overcome the impacts of climate change — is the central focus of this study. Several factors significantly influence the resilience of businesses and organizations, including economic and social conditions, leadership, access to information, social cohesion, and environmental concerns. Interviews, resilience indicators, and statistical analysis are among the quantitative and qualitative approaches used to measure resilience. According to the study, businesses in Greece have made some efforts to become more resilient; however, there are still certain gaps that need to be addressed. Successfully confronting the challenges posed by climate change requires a holistic resilience strategy, improved communication, and greater collaboration among stakeholders.

Keywords

Organizations, Resilience, Climate, Strategy, Model

ANALYSIS AND DESIGN OF A DIGITAL ASSISTANT FOR MENTAL HEALTH ISSUES

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ABSTRACT

This thesis focuses on the study, analysis, and design of a Digital Assistant intended to support users in matters related to Mental Health. The project falls within the broader domain of Information Systems and explores how technology can be utilized to offer psychological support and empowerment—particularly for individuals who may hesitate to seek help from mental health professionals directly.

The study begins by presenting the theoretical background that links Information Systems with the field of Mental Health, emphasizing system functionality, architecture, and core requirements. It then proceeds to describe the design of the digital assistant, aiming to create a friendly and approachable conversational environment. The assistant is designed with the aid of artificial intelligence and natural language models, and its structure includes responses to frequently asked questions, self-help techniques, and supportive dialogue.

Particular emphasis is placed on the system's architecture, which follows a client-server model and leverages open-source technologies to ensure development efficiency and scalability. In addition, issues of data security and privacy are thoroughly examined, given the sensitive nature of the information involved. The thesis concludes with proposals for future system enhancements, such as the integration of personalization features, mobile accessibility, and automated routing to professional support services when needed.

Overall, the study highlights the potential of digital tools to offer meaningful support in the field of mental health, especially when they are designed with a focus on user-centricity, safety, and reliability.

Keywords

Digital Assistant, Mental Health, Information Systems, Artificial Intelligence, Decision Support

NATURAL LANGUAGE PROCESSING FOR THE MANAGEMENT OF STANDARD OPERATING PROCEDURES

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ABSTRACT

This thesis explores ways to enhance the management and utilization of Standard Operating Procedures (SOPs) in industrial environments through the application of Natural Language Processing (NLP) techniques. Following a methodological approach that combines literature review and analysis of current practices, it identifies and examines the main challenges in today's implementation of SOPs, such as ambiguity in instructions, difficulty in retrieving relevant information, and lack of connection with historical incident data.

In response to these challenges, the study proposes the development of an NLP-powered system consisting of two complementary subsystems: a SOP Management and Evaluation System and a Digital Guidance Assistant. The former focuses on the automatic assessment of SOP completeness and consistency, utilizing technologies such as Semantic Similarity, Keyphrase Extraction, and Named Entity Recognition. The latter aims to support workers during procedure execution by enabling interactive information retrieval, detecting vague or critical instructions, and offering voice-based guidance.

The thesis presents a detailed analysis of the necessary NLP technologies, the system's architecture and information flow, and includes realistic application scenarios in the plastic manufacturing sector. These examples demonstrate the tool's potential to improve compliance, understanding, and safety during SOP execution. In conclusion, this study highlights the potential of NLP as a transformative tool for improving the design and application of SOPs, while emphasizing the importance of tailoring such solutions to the specific needs of each industrial context.

Keywords

Natural Language Processing (NLP), Standard Operating Procedures (SOPs), Digital Assistant, Industrial Innovation, Large Language Models (LLM)

STUDYING THE ENERGY CONSUMPTION OF END-USE SECTORS IN THE EUROPEAN UNION

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ABSTRACT

Energy consumption is a decisive factor for the economic development of a country, directly influencing the citizens' quality of life and shaping the path towards a more sustainable future. At the same time, it lies at the core of the European Union's (EU) strategies, which aim to reduce dependance on fossil fuels and promote the use of Renewable Energy Sources (RES), with the ultimate goal of adopting a sustainable and energy efficient model. In this thesis, we initially study the energy consumption of EU Member States during the period 2011-2022, investigating both the time evolution and the changes in the main end-use sectors: industry, commercial and public sector, transport and households. Simultaneously, we examine the penetration of renewable energy sources in the electricity, transport and heating/cooling sectors, highlighting energy differences among the Member States. Subsequently, we attempt to group the EU countries, based on their levels of energy consumption and the share of energy derived from renewable energy sources, using cluster analysis methods. Next, we use Linear Mixed Effects Models to investigate the correlation between consumed energy from renewable energy sources and a set of socio-economic and institutional factors, such as Gross Domestic Product per capita, Foreign Direct Investment, Research and Development expenditure, the value added from agriculture, forestry and fishing, the urban population growth rate, the Human Development Index, industrial activity, the European Green Deal and the Doha Amendment. The results of the study are valuable tools for understanding the differences among Member States in their progress towards green transition, as well as for the future design of effective EU strategies. Specifically, the cluster analysis highlighted two stable groups, one of which includes countries with low renewable energy consumption, while the other comprises states the recorded high renewable energy consumption, whereas Linear Mixed Effects Models identified time, Gross Domestic Product per capita, Research and Development expenditure, industrial activity, the impact of the European Green Deal and the

Human Development Index (HDI) as significant determinants of renewable energy sources consumption.

Keywords

Energy consumption, Renewable Energy Sources (RES), European Union (EU), Cluster Analysis, Linear Mixed Effects Models

RECOMMENDATION SYSTEMS BASED ON ARTIFICIAL INTELLIGENCE TECHNOLOGIES

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ABSTRACT

In the present diploma thesis recommendation systems are explored as a key tool for the effective management and utilization of the vast amount of information in the modern digital environment. Emphasis is placed on the fundamental architectures that leverage content, collaborative, demographic and knowledge data, as well as hybrid approaches that combine different techniques to enhance accuracy and flexibility. Modern applications of artificial intelligence are presented in great detail, including artificial neural networks, natural language processing methods, autoencoders, Bayesian Models and Generative Adversarial Networks (GANs). The integration of these technologies strengthens the systems' ability to provide personalized, accurate and dynamically adaptive recommendations.

The challenges regarding the management of large volume and diverse types of data, the need for interpretability, and the continuous adaptation of systems on the evolving user requirements are highlighted. Through a case study, an information recommendation system for job postings is developed, which utilizes artificial intelligence techniques to optimize the recommendation process. The analysis includes the definition of functional and non-functional requirements, use cases and user stories, as well as the data flow diagrams and entity-relationship diagrams, that capture the system's architecture. The system design is completed with the development of the rapid prototype, which aims to create a user experience that combines usability, clarity and interactivity.

Finally, the case study emphasizes the role of modern artificial intelligence technologies as a catalytic factor for enhancing the personalization and reliability of recommendation systems. At the same time, it outlines the potential for further development and implementation of these systems across various fields, with the goal of improving the recommendations provided and enhancing the user experience.

Keywords

Recommendation Systems, Artificial Intelligence, Machine Learning, Data Management, Personalization.

DIVISION OF APPLIED MECHANICS, TECHNOLOGY OF MATERIALS AND BIOMECHANICS (SEPTEMBER 2025)

VLEO SATELLITES: AN OPTIMIZED ENGINEERING DESIGN APPROACH

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ABSTRACT

The increasing demand for high-resolution Earth observation, low-latency communications, and cost-efficient access to orbit has directed attention toward Very-Low Earth Orbit (VLEO) satellites, which offer improved spatial resolution, reduced radiation exposure, and natural compliance with deorbit regulations. However, the enhanced aerodynamic drag at these altitudes poses severe constraints on mission lifetime, requiring innovative propulsion solutions. Among them, air-breathing electric propulsion (ABEP) has emerged as a promising technology, exploiting residual atmospheric particles as propellant to enable sustainable operations. This thesis presents an optimized engineering design approach for VLEO satellites integrating ABEP, combining high-fidelity aerodynamic modeling with surrogate-assisted optimization. First, the environmental characteristics of VLEO are analyzed, including drag forces, radiation environment, intake heating, and feasible flight envelopes. A novel satellite geometry is proposed, consisting of an aerodynamic forebody and dual intake ducts coupled with a rectangular payload section to balance aerodynamic efficiency, manufacturability, and payload capacity. The aerodynamic behavior is modeled using the NRLMSISE-00 atmosphere, while Direct Simulation Monte Carlo (DSMC) simulations performed with SPARTA quantify drag and scattering coefficients. To overcome the computational cost of exhaustive DSMC evaluations, a surrogate-based methodology is developed, employing screening plans, optimized Latin Hypercube Sampling, Kriging with Partial Least Squares, and adaptive infill strategies. This framework supports a Particle Swarm Optimization (PSO) process targeting the maximization of the thrust-to-drag ratio under realistic geometric and propulsive constraints. Results demonstrate that rectangular geometries achieve competitive performance compared to circular cross-sections when system-level integration is considered, while the surrogate-assisted optimization significantly reduces computational effort. The study validates the feasibility of ABEP-powered missions in VLEO and establishes a robust methodology for future satellite design.

Keywords

Optimization, Satellites, Surrogates, DSMC, Propulsion, Simulation

CALCULATION OF FFR INDEX FOR THE DIAGNOSIS OF ARTERIAL STENOSIS SEVERITY USING COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT

In the present thesis, a parametric analysis is conducted to evaluate the validity of the smartFFR method, a novel approach to estimate the Fractional Flow Reserve (FFR) index based on CFD.

This index is used to assess the functional significance of coronary stenoses, which are responsible for CAD, the leading cause of deaths worldwide. Accurate diagnosis of the disease is considered crucial for effective treatment with the invasive calculation of FFR currently proved to be the most reliable method. Despite its high validity, this method has been associated with some significant disadvantages, mainly related to its invasive nature, the cost of the procedure and the requirement for vasodilators drugs. Furthermore, due to the time required to obtain the results, its actual clinical application remains significantly limited.

To address these limitations, innovative alternative techniques of FFR calculation are being developed, leveraging Computational Fluid Dynamics, Artificial Intelligence, Machine Learning, and advanced vascular imaging methods. Among these FFRCT and caFFR have been extensively studied and approved for clinical use. However, many other methods are already proposed but have yet to be thoroughly evaluated like FFRangio, QFR, vFFR and smartFFR.

This study focuses on the smartFFR method and studies its reliability using invasive measurements of the index as a comparison criterion. The method is based on computational simulation of blood flow and 3D reconstruction of artery models derived from coronary angiography images, implemented using ANSYS FLUENT software. Four different blood flow models were selected for analysis: Newtonian, Casson, Cross, Carreau-Yasuda.

The reliability of the methods was evaluated through statistical analysis, which included the following indicators: Pearson correlation coefficient, Bland-Altman plot, and receiver operating characteristic (ROC) curve. The results of the study showed that the smartFFR method with blood simulation using the Newtonian or Casson model were the only acceptable alternatives, but only under certain conditions. The Cross and Carreau-Yasuda models were found to be completely unreliable and were therefore rejected.

Keywords

Coronary Artery Disease, Fractional Flow Reserve, Computational Fluid Dynamics, smartFFR, Statistical Analysis.

CONCEPTUAL DESIGN AND STRUCTURAL ANALYSIS OF A HYBRID AIRSHIP

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ABSTRACT

The purpose of the present diploma thesis entitled 'Study and analysis of basic characteristics of a Hybrid Aircraft is the presentation of the lifting methods and their use for the preliminary design of a tethered unmanned hybrid airship. The design process includes flight simulations of the airship models, selection of suitable construction materials and structural analysis using the finite element method. Design choices will be made based on weight criteria. The airship is intended for use in safety surveillance applications, therefore the design will be centered around the ability to lift a small payload at a suitable altitude. At the end of the study, several models for the airship will have emerged and will be judged on their results.

Keywords

Hybrid Airship, Semi-rigid Structure, Weight, Model, Tether

STUDY OF MECHANICAL PROPERTIES IN MICRO AND NANO SCALE OF POLYMERIC MATERIALS FOR USE IN ORTHOPEDIC APPLICATIONS

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ABSTRACT

The evolution of biomaterials began with the early applications of natural materials in antiquity and has developed through three generations: the "passive" first generation, emphasizing biocompatibility; the second generation, incorporating bioactive and biodegradable materials; and the modern third generation, which aims for tunable interactions with tissues and promotes regeneration through advanced techniques and hybrid systems.

Within this context, the present study investigates polymeric biomaterials with potential orthopedic applications, focusing on polylactic acid (PLA), poly(ε-caprolactone) (PCL), and highdensity polyethylene (HDPE), due to their biocompatibility, processability, and broad range of mechanical properties.

The experimental design combines complementary techniques for comprehensive evaluation at the micro- and nanoscale. Atomic force microscopy (AFM) was used to capture the surface topography and quantify roughness, scanning electron microscopy (SEM) revealed morphological features of the microstructure and possible surface irregularities or flow marks, while nanoindentation determined the effective elastic modulus (Er) and hardness (H), providing insight into the local mechanical response.

Analysis showed that variations in morphology—such as spherulitic texture or flow marks—correlate with increased roughness values and are reflected in variations of the elastic modulus and hardness, without necessarily exhibiting a monotonic relationship with molecular weight. Overall, polylactic acid (PLA) exhibited higher stiffness and hardness with low to moderate roughness, poly(ε-caprolactone) (PCL) displayed low stiffness with variable roughness depending on processing history, and high-density polyethylene (HDPE) showed intermediate values with characteristic morphological heterogeneities.

These findings outline the advantages and limitations of polylactic acid (PLA), poly(ε-caprolactone) (PCL), and high-density polyethylene (HDPE), providing a foundation for targeted property optimization and translation to specific clinical orthopedic scenarios.

Keywords

Atomic Force Microscopy (AFM), Nanoindentation, Polylactic acid (PLA), Poly(ε-caprolactone) (PCL), High-density polyethylene (HDPE)

SIMULATION OF BLOOD FLOW DYNAMICS IN PATIENT - SPECIFIC GEOMETRIES OF LEFT ATRIUM

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ABSTRACT

This work focuses on the simulation and computational analysis of the blood flow that develops inside the left atrium of the human heart. More specifically, its main objective is the quantitative analysis of the flow characteristics that appear in a specific region of the left atrium, the left atrial appendage. The left atrial appendage is a small protrusion of the left atrium, whose complex and diverse morphology makes it the primary region for blood stasis and, consequently, the most frequent site of thrombus formation within the heart. To achieve this goal, two different, patient-specific geometries were utilized, which were extracted from Computing Axial Tomography (CAT or CT scan) data and reconstructed as three-dimensional digital models. These geometric models were discretized into high-fidelity computational meshes, which formed the basis for the numerical simulations. The analysis was conducted according to the principles of Computational Fluid Dynamics (CFD), by solving the Momentum and Continuity equations. Appropriate boundary conditions were applied to simulate a complete cardiac cycle under a pathological velocity profile, which is characteristic of conditions that promote thrombosis. The ultimate purpose of the analysis is the comparative evaluation of the results from the two geometries and the drawing of conclusions. The quantification of the risk for thrombogenesis was achieved through the use of hemodynamic indices. A central role in the evaluation is played by the Relative Residence Time (RRT) index, which quantifies the time that blood particles remain in regions of low velocities and stresses, functioning as a strong prognostic indicator of blood stasis. The results aim to highlight how the construction of patient-specific computational models can enhance medical diagnosis, support clinical decision-making, or aid in the implementation of preventive therapies for thromboembolic events.

Keywords

Computational Fluid Dynamics, Left Atrial Appendage, Hemodynamics, Thrombosis, Patient-specific Simulation

APPLICATION OF ARTIFICIAL INTELLIGENCE FOR THE LUMEN SEGMENTATION IN OCT IMAGES

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ABSTRACT

Lumen segmentation is fundamental for the diagnosis, monitoring and treatment of coronary artery disease. Optical coherence tomography (OCT) provides high-resolution intravascular images, but OCT lumen segmentation is typically performed manually, requiring time and expertise due to lumen morphology and OCT-specific artifacts. This thesis develops and evaluates an artificial intelligence (AI) framework for automated lumen segmentation in intravascular OCT images. The proposed model is a lightweight convolutional neural network (CNN) with an encoder-decoder architecture, designed to balance accuracy and computational efficiency. During the development phase, different design choices are systematically examined, including target representation, optimizers, and data augmentation strategies, in order to identify the most effective configuration. The final framework integrates lumen and adventitia prediction, the AdamW optimizer, and a tailored augmentation pipeline. Evaluation is performed using patient-level six-fold cross-validation to prevent data leakage and provide reliable estimates of generalization, with segmentation quality assessed through standard evaluation metrics and visualization of predictions. A resolution study is also conducted to investigate the impact of input size on performance. Finally, considerations of training and inference time are included to highlight the trade-off between segmentation accuracy and computational cost. Overall, the study demonstrates that accurate and efficient lumen segmentation is achievable with a lightweight CNN and a limited dataset through careful design choices, highlighting the clinical potential of AI methods in real-time OCT analysis.

Keywords

Coronary Artery Disease, Optical Coherence Tomography, Lumen Segmentation, Convolutional Neural Networks, Artificial Intelligence

HAIL IMPACT ON A WIND TURBINE BLADE

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ABSTRACT

The continuous growth of wind energy has established wind turbines as a vital component of modern energy infrastructure for generating electricity from renewable sources. Despite their significant technological advancements, wind turbines continue to face considerable challenges, among which protecting blades against hail impact is particularly critical. Hail impact can cause severe damage to the composite materials used in blade construction, negatively affecting their performance, reducing their service life, and increasing maintenance and repair costs. This diploma thesis investigates the effect of hailstorms on the strength and functionality of wind turbine blades, focusing on the analysis of damage mechanisms and the resilience of composite materials. Initially, an extensive literature review is conducted on composite materials employed in blades and their mechanical properties under dynamic impact conditions. The characteristics of hailstorms are extensively analyzed, emphasizing the physical properties of hailstones, such as density, size, and impact velocity, which dictate the dynamic response of the blade. Furthermore, the study utilizes numerical simulations of hail impact on composite structures using the Smooth Particle Hydrodynamics, SPH, method within the LS - Dyna finite element software. Finally, the simulations are conducted at two levels, initially employing simplified plate geometry and subsequently extending to a realistic wind turbine blade model, thereby ensuring a closer representation of actual operating conditions and a more accurate evaluation of the results.

Keywords

Hail Impact, Wind Turbine's Blades, Composite Materials, Particle Collision Effect, Damage of Composite Materials

MECHANICAL AND THERMAL CHARACTERIZATION OF COMPOSITE MATERIAL WITH THERMOPLASTIC MATRIX

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ABSTRACT

This thesis examines the mechanical and thermal characterization of a composite material with thermoplastic matrix. Thermoplastic composite materials represent are a growing category of materials with excellent mechanical and thermal properties, making them suitable for demanding applications.

Initially, the fundamental principles of thermoplastic composite materials are presented, along with their classification and advantages over conventional composite and metallic materials. The study then describes the experimental procedures conducted to study the mechanical properties of the material. These include tensile, compression, shear, impact and bolted connection experiments.

The results of the experiments are analysed and compared with bibliographic data and standard testing protocols. The findings indicate that the thermoplastic composite material exhibits high strength, resistance to thermal stresses and recyclability, characteristics that make it a candidate for replacement of thermosetting materials in various applications.

Keywords

Composite materials, Thermoplastics, Experimental methods, Mechanical properties, Recyclable materials

STUDY OF FRICTION STIR WELDING OF AEROSPACE ALLOY 2024

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ABSTRACT

The present study aims to investigate the Friction Stir Welding (FSW) of the aerospace-grade alloy 2024-T351 and to evaluate the mechanical properties of the bonds.

FSW is an innovative solid-state welding technique, invented in 1991. It operates by plunging a non-consumable rotating tool into the edges of the materials to be joined, generating heat through friction and plastic deformation, which leads to material stirring and permanent bonding. Its advantages are significant, as it is a "green" technology requiring low energy, does not use shielding gases or filler materials, and results in a fine-grained microstructure, free of cracks and with minimal material distortion. It is particularly effective for aluminum alloys such as AA2024-T351, which are difficult to weld using conventional fusion-based methods.

For the experimental process, a CNC milling machine was used. Three tools were designed and manufactured from tool steel, each with different pin geometries (plain cylindrical, threaded cylindrical, and plain conical) and a concave cylindrical shoulder. Given the specimen thickness (5 mm), a pin length of 4.8 mm and a diameter of 5 mm were selected. A custom metal fixture with a 3-degree tilt was built to support the specimens, ensuring the required tool angle. With a traverse rate of 30 mm/min and rotational speed of 600 min-1, two welds were produced using a plain cylindrical tool and a threaded cylindrical tool, respectively.

The textures were successful up to the midpoint of the seam but showed cracking afterward for the plain tool, and homogeneous along the weld for the threaded tool. The cross-sectional analysis of each weld revealed tunnel type defects, which had a negative impact on the mechanical properties of the joints. The hardness profile showed a reduction in the nugget zone with the lowest values observed in low hardness zone. In terms of tensile strength, the maximum value obtained using the plain tool was 77,62 MPa while the maximum value for the threaded tool was 69,24 MPa. These results highlight the susceptibility of weld quality to tool geometry and process parameters and underline the need for further optimization to enhance joint performance.

Keywords

Friction Stir Welding, Tool Geometry, Microstructure, Mechanical properties

DAMAGE ASSESSMENT IN METALLIC MATERIALS WITH EDDY CURRENTS AND THE USE OF ARTIFICIAL INTELLIGENCE

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ABSTRACT

This thesis focuses on the study and development of a dimensional characterization model for surface and subsurface cracks, aimed at addressing the problem of damage estimation in the context of Non-Destructive Testing (NDT) using the Eddy Current method. The research falls within the scientific field of Artificial Intelligence and is based on modern Machine Learning techniques.

The theoretical part of the work presents a comprehensive review of the existing literature, identifying different takes on the solution of the inverse problem of Eddy Current Testing. Subsequently, a solution framework is proposed, combining magnetic field simulations measured by an eddy current probe over defective materials, with the objective of improving the quality and reliability of defect evaluation in tested structures.

The methodology is implemented through numerical simulations and algorithm development, resulting in an Artificial Intelligence model capable of predicting the depth and height dimensions of cracks in non-ferromagnetic materials. Experimental validation is conducted using a custom-designed eddy current probe, capable of detecting subsurface cracks. The results are evaluated based on the percentage of accurate predictions of crack dimensions, as well as the percentage of predictions that fall within specified tolerance thresholds.

The findings demonstrate the functionality and effectiveness of the proposed solution, confirming its suitability for practical application in the field. Finally, suggestions for future research are provided, aiming at further improving and extending the current work.

Keywords

Eddy currents, Non-Destructive Testing, Inverse problem, Artificial Intelligence, Machine Learning

LCA ANALYSIS OF A COMPOSITE AIRCRAFT WING

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ABSTRACT

This thesis examines the overall environmental performance of two alternative aircraft wing design options for a narrow-body configuration: one made of carbon fibre reinforced composite materials (CFRP) and one made of aluminium. The aim of the study is to provide a quantitative comparison of the environmental footprint of these two design alternatives using the Life Cycle Assessment (LCA) methodology, in accordance with the ISO 14040 and ISO 14044 standards.

The analysis covers all life cycle stages — from conceptual design, material processing and manufacturing to operation, maintenance, and end-of-life management. The modelling was conducted using the openLCA software, based on data from relevant literature and the ELCD (European Reference Life Cycle Database), while the impact assessment was performed according to the ReCiPe 2016 method. The individual processes (such as material machining, surface preparation and cleaning, coating and protection application, assembly and mechanical fastening, testing and inspection, in-service maintenance, disassembly, material sorting, and recycling) were quantitatively analysed through corresponding energy and material flows, allowing a systematic comparison of the two technological alternatives under a common functional framework.

The results indicate that the CFRP wing achieves approximately 20% lower greenhouse gas emissions compared to the aluminium one, mainly due to its lower structural weight and the consequent reduction in fuel consumption during the operational phase. Improvements are also observed in the categories of human toxicity and water consumption, although the production of composite materials demonstrates higher energy intensity.

Overall, the study highlights the potential of composite materials as a more sustainable choice for the modern aerospace industry, provided that they are combined with efficient end-of-life fibre recovery and recycling strategies.

Keywords

Life Cycle Assessment (LCA), Aviation Industry, Composite Materials (CFRP), Environmental Footprint, Narrow-Body Aircraft Wing

DEVELOPMENT OF PREDICTIVE MODELS OF OSTEOPOROSIS USING ULTRASOUNDS IN "IN VIVO" CONDITIONS

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ABSTRACT

This study examined predictive models of osteoporosis using ultrasound in vivo. In the initial stage, the part of the heel that concerns the cancellous bone is calculated, and then its acoustic properties are determined using ultrasound, more specifically through the Through Transmission method, in order to classify it as osteoporotic or osteopenic. Seventeen women participated in the experimental procedure, most of whom were mothers and daughters, and measurements were taken on both legs in a sitting position. Data was also collected on the lifestyle of women with or without osteoporosis, and medical histories were taken, with the aim of creating an initial database. The results of the experimental measurements showed a slight deviation in the relevant measurements due to minimal leg length discrepancy and errors during the experiment. At the same time, two databases were identified, one of which was merged with the one created experimentally, and used to create machine learning models. More specifically, the k-Nearest Neighbours (k-NN), Logistic Regression, SVM linear and non-linear, Random Forest, and Gradient Boosting algorithms were applied and compared with appropriate metrics. In the first dataset, the XGBoost algorithm performed better, while in the second, Logistic Regression performed better. Overall, all algorithms performed better on the first dataset. Finally, age, body mass index, and race/ethnicity were characteristics that contributed to the best prognosis of the algorithms.

Keywords

Machine learning, Predictive models, Osteoporosis, Heel, Ultrasound

INVESTIGATION OF DYNAMIC RESPONSE OF A ROD WITH PIEZOELECTRIC RESONATORS

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ABSTRACT

Many engineering structures, like aircraft, buildings, machines, are constantly subjected to dynamic loads: earthquakes, aerodynamic, rotary forces, leading to unwanted vibrations. Modern technological advancements, especially in industries such as aerospace and wind energy built the foundations of the "lightweight" philosophy. Aluminum alloys and composites gradually dominated the fields, for environmental and financial purposes. However, the majority of these structures are flexible, meaning that large displacements are expected under loads, setting the structural integrity in danger or leading to human discomfort (for buildings and vehicles). It is thus necessary to develop anti-vibrational devices.

The main methods for dealing with vibrations are isolation and protection. In the former, a usual practice is the deployment dampers and springs, while in the latter, a common configuration is the tuned mass damper (TMD), usually modelled as a resonator, a simple mass-damper element, and has the ability to create an anti-resonance in the structure, dependent on its natural frequency. Their analysis and deployment are relatively simple, but the bandwidth it can affect is limited, while also adding more mass to the structure and some robustness issues due to uncertainties and change of parameters of the structure. As a solution, the deployment of multiple TMDs is suggested, which can be tuned to the same frequency, a band, or multiple natural frequencies, with the goal of multimodal control. In the literature, sometimes these configurations are named "metastructures", inspired by metamaterials, and their applications are not limited to experimental models, as they are also met in the industry (scyscrapers, wind turbines).

Another antivibrational method is piezoelectric patches, which are bonded in structures, in order to create electromechanical coupling. The patches are connected to a shunt circuit via electrodes, whose purpose is to convert the kinetic energy to thermal energy, causing an attenuation of the vibration. Their capabilities are outstanding, but their applications are

limited in the academic environment, possibly due to their overwhelming cost, which is a leading factor in the industry.

The scope of this thesis is the investigation of dynamic response of a rod with multiple piezoelectric resonators, based on the dissertation named ”Development and Application of a Novel Semi-Active Piezoelectric Tuned Mass Damper for Robust Vibration Control of Flexible Structures with Focus on Airframe Structures”, which analyses the dynamic response of a piezoelectric stack connected to an RL circuit, replacing the spring element of the conventional TMD. It is proven that the electromechanical coupling generates two anti-resonances in the main structure, which can be tuned based on the inductance of the shunt circuit, achieving multimodal control, while the resistance can damp the amplitudes of modes. Different cases of commercially available stacks will be studied, both for vibration control and energy harvesting efficiency, which is possible by substituting the resistor with a suitable transducer.

Keywords

Piezoelectric Resonator, Multiple Tuned Mass Dampers, Metastructure, Vibration Control, Energy Harvesting

LIFE PREDICTION OF WIND TURBINE ROTOR BLADES UNDER VARIABLE AMPLITUDE CYCLIC LOADING

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ABSTRACT

Currently, in the context of rotor blade fatigue design, the standard practice in certification routines for life prediction is to ignore the σ_2 and σ_6 stress components and to consider only σ_1, under the assumption that σ_1 governs the critical failure mode of fibre fracture. Although practical, this assumption is overly simplistic, and additional stress components as well as local three-dimensional effects may play a role in damage accumulation.

This thesis investigates the adequacy of the standard approach by applying it to a real blade and comparing it with several alternative life-prediction methodologies. Four approaches are examined: (i) the standard σ_1-based practice, (ii) a methodology identical to the standard one but that considers only σ_2 or σ_6, (iii) an approach that considers all three plane stress components, using the tensor polynomial failure criterion adapted for fatigue, and (iv) a modified last-ply-failure criterion. Furthermore, a more detailed finite element–based stress analysis method is implemented and compared against standard sectional analysis tools.

The study concludes that while the non-standard approaches are experimentally verified only at the coupon material level, but lack experimental validation in rotor blade full-scale testing, their comparison with the established methodology indicates that σ2 and σ6 components have a significant impact on damage calculations and should not be ignored. Finally, regarding the stress analysis methodologies, it was observed that the more accurate model yielded more optimistic predictions, offering potential pathways toward more efficient use of materials and improved design practices.

Keywords

Rotor blade, Polymer-matrix composites (PMCs), Fatigue, Life prediction, Variable Amplitude Loading

DIVISION OF DESIGN AND MANUFACTURING (SEPTEMBER 2025)

DYNAMICS OF RIGID AND FLEXIBLE ROTOR SUPPORTED BY ACTIVE MAGNETIC BEARINGS

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ABSTRACT

The dynamic analysis of a rotating shaft supported by bearings is very important, since this system is the main way that power transfer from a motor is achieved. However, studying such systems can be quite complex, especially when the shaft is supported by Active Magnetic Bearings (AMBs). The difficulties come from the phenomena that occur during shaft rotation, the special characteristics of the AMBs and the control systems that operate with them.

In this thesis, simulation models will be developed for two types of Rotor–AMB setups. The first is a Jeffcott rotor supported at both ends with AMBs, and the second is an overhang rotor supported at its free end by an AMB. For each type two models will be created: the first model will assume the shaft is rigid and the second one that the shaft is flexible. The work starts with a theoretical study of the dynamic behavior of shafts and the operation of AMBs. Then, the rigid shaft models are created. To do this, the equations describing shaft motion, AMB operation, control systems, and excitation forces must be laid out for each case. From these equations, a block diagram is built in MATLAB-Simulink, where the input is the chosen disturbance and the output is the rotor displacement.

The flexible shaft simulations are carried out in the finite element software Ansys Workbench. This requires designing the 3D geometry of the rotors and defining their material. Then the finite element mesh is generated and the support condition is specified. The AMBs are modeled through the stiffness and damping they provide in each control direction.

Finally, once the models are created, modal analyses is performed to find the critical speeds of each rotor. Harmonic analyses with unbalance mass is also carried out to obtain shaft displacements and frequency response diagrams. In addition, the effect of increasing the number of poles of the AMBs on the rotor response will be studied.

Keywords

Active Magnetic Bearings, Rigid Rotor, Flexible Rotor, Dynamic Analysis of Shafts

DESIGN OF UNDER LIMP PROSTHESIS WITH CONTROLED ROBUSTNESS USING PNEUMATIC MUSCLES ACTUATORS

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ABSTRACT

In the present diploma thesis, the design of a lower-limb prosthesis with controlled robustness is carried out. Following the steps of fundamental engineering design, the corresponding problem definition was established, and sufficient information was collected in order to conceptualize an appropriate design idea for the prosthesis. The CAD (Computer-Aided Design) software Shapr3D was used to achieve the initial prototype design, and subsequently to analyze the geometry under different motion scenarios, with the aim of ensuring suitable robustness. The PMA (Pneumatic Muscle Actuators), which constitute the driving mechanism for robustness control, were also designed. Static and dynamic analyses were conducted for the main machine elements that comprise the mechanism and form the artificial limb. Furthermore, FEA (Finite Element Analysis) methods were applied to analyze the stresses developed in the prosthetic joint under static and dynamic loading. Once the above data were collected, the appropriate materials were selected in order to ensure both strength and reduced mass of the prosthesis, and included the control mechanism for the pneumatic muscles. Subsequently, the three-dimensional model of the artificial limb was constructed using the CAD (Computer-Aided Design) software DS Catia, and the material selection was validated through simulations with ANSYS.

Finally, the conclusions and comments derived from the design results were presented.

Keywords

Design, Prosthetic, Pneumatic muscle, Load analysis, Graphic design

DAMAGE DIAGNOSIS FOR A LABORATORY SCALE AIRCRAFT STABILIZER UNDER UNCERTAINTY VIA RANDOM VIBRATION RESPONSE METHODS

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ABSTRACT

This thesis focuses on the diagnosis of damages in a scaled laboratory aircraft wing under realistic scenarios of excitation, uncertainty, and damage. The effectiveness of damage detection and identification is particularly critical in aerospace structures, where passenger safety is paramount. Consequently, there arises a need to develop methods that enable not only timely diagnosis but also reliable prediction of various damage scenarios. Special emphasis is placed on the ability of these methods to distinguish actual damage states from false alarms that may arise due to variations in the initial conditions of the system under study. Specifically, changes in the wing mass, often caused by ice accretion, may be erroneously interpreted as structural damage. For this reason, the deliberate addition of mass to the structure is examined in this work as an uncertainty scenario, as well as the ability to correctly recognize it as a healthy state. Subsequently, the damage scenarios investigated concern the reduction of tightening torque in four different bolts of the wing, which include both mild and severe loosening levels. This represents a realistic damage condition, mainly attributed to the stresses experienced by the bolts during flight. Under the prism of realistic simulations, the structure is excited by two shakers, which makes the identification process more challenging, while simultaneously more representative of real conditions due to the multiple forces acting on the stabilizer wing during flight. The responses are recorded by two types of sensors, namely accelerometers and strain gauges, ultimately leading to a comparative evaluation of their performance. The signals used concern response-only data, resembling real-time measurements where the excitation is not always available. The diagnosis process is based on the classical Multiple Models methodology, as well as the integration of PCA, exploiting features of parametric models, selected as MISO-TF-ARX. This specific choice is justified by the fact that model significantly mitigates uncertainties arising during experiments, primarily due to the interaction of the two exciters. The study concludes that the incorporation of PCA leads to improved results, achieving detection rates of 100% and correct diagnosis rates of 80%.

Keywords

aircraft wing, vibration, two exciters, uncertainty, mass addition, damage detection, bolt loosening

A WIRE DIRECTED ENERGY DEPOSITION (DED) ADDITIVE MANUFACTURING (AM) PROCESS MODEL TOWARDS PART QUALITY OPTIMIZATION

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ABSTRACT

The Directed Energy Deposition (DED-LB) process, using a laser as the heat source and wire as the feedstock material, enables the fabrication of complex geometries directly from 3D design specifications. Despite its advantages in reducing component development time, minimizing resource requirements, and producing high-quality solutions without inherent manufacturing defects, the process exhibits unstable behavior when operating conditions change during component fabrication. Ensuring high-quality components requires adaptive control techniques that collect data from monitoring systems and simulation models, responding dynamically to process variations. Recognizing the importance of control systems, this work focuses on developing control strategies using a physics-based process simulation tool, implemented with the finite difference computational method to ensure rapid execution. The initial steps in developing the control involved validating the tool's accuracy and reliability by testing its limits and assessing its parametric sensitivity, alongside experimental validation of its ability to qualitatively and quantitatively simulate the process. In contrast to the machine learning–based data analysis methods commonly used to date, a controller is developed that maintains the dimensions of the molten material zone and the penetration depth between layers at desired levels through an iterative procedure. The controller's performance is validated through real-world experiments, demonstrating complete agreement in qualitative characteristics, pinpointing optimal decision-making moments, and highlighting the need to adapt control strategies according to the desired process parameters.

Keywords

Metal Additive manufacturing, Directed Energy Deposition, Laser Wire, Process control for optimization, Simulation

STRESS ANALYSIS OF SPIRAL BEVEL GEARS UNDER THE EFFECT OF FRICTION AND SURFACE

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ABSTRACT

Spiral-bevel gears are among the most fundamental mechanisms for the development of vehicle differentials and more generally are used to transmit motion between intersecting shafts. This thesis begins with a theoretical overview of all types of gears commonly found in modern mechanical engineering. It then presents and analyzes the mathematical formulas related to the geometric design and stress analysis of gear teeth. The main objective of the study is the analysis of stresses, taking into account factors such as friction and surface roughness.

A review of the relevant bibliography is conducted, comparing various theoretical models for friction and roughness, and specifically selecting the Coulomb model for friction and the Bowden–Tabor model for surface roughness. Subsequently, MATLAB code is developed incorporating these models. Calculations are carried out for three different material types and two different pressure angles, aiming to compute the stresses under three conditions, without friction, with a constant coefficient of friction (μ = 0.2), and with a variable coefficient of friction depending on the roughness of each material.

Finally, a gear model is developed in the ANSYS simulation environment, after first designing the CAD files in SolidWorks. The process concludes with a comparison and evaluation of the results, confirming the reliability of the proposed model.

Keywords

Spiral bevel gears, Friction, Surface roughness, Finite element method, Pressure angle

VIBRATION RESPONSE-ONLY BASED DAMAGE DIAGNOSIS FOR A POPULATION OF 4-DOF NOMINALLY IDENTICAL SYSTEMS UNDER UNCERTAINTY VIA PARAMETRIC MACHINE LEARNING METHODS

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ABSTRACT

This thesis investigates the optimal method for detecting artificial damage scenarios in a standard model with four degrees of freedom (4-DOF), based on oscillation acceleration signals. The significance of the topic studied is high, as the timely detection of damage in a structure is directly related to its efficiency and the safety of the user. The monitoring of the structural integrity of constructions is achieved through the study of their dynamic characteristics. The signals collected from an accelerometer and analyzed both non-parametrically, using the Welch method, and parametrically, using autoregressive (AR) models, to identify the individual dynamic characteristics of the system.

The effect of nine artificial failure scenarios on the model's dynamics is then studied, considering the uncertainties due to changing environmental operating conditions and factory inaccuracies. Specifically, three types of damage are examined, which result in a reduction in the stiffness constant of one of the three springs of the structure, by 7, 14 and 24%. For the modeling of uncertainties, a homogeneous healthy population with 200 structural elements and nine damaged populations (one for each damage scenario) consisting of 100 elements each, which give a total of 1100 response signals.

The structural integrity diagnosis process is divided into three stages: (1) damage detection, (2) damage localization and (3) damage severity. The damage detection is performed using three different methods, one unsupervised (U-MM-AR) and two supervised (SVM and 1D CNN), which are then enhanced using PCA transformation. The results highlight on one hand the effectiveness of the PCA transformation in reducing the impact of uncertainties and on the other hand the efficiency of supervised methods, and particularly the SVM algorithm in fault detection. Subsequently, an attempt is made to classify damage through the detection of their location and size, with PCA-enhanced 1D CNN achieving better performance. The results are evaluated using Confusion Matrices and ROC Curves.

Keywords

AR, Varying Environmental and Operating Conditions, Uncertainties, Population, Damage Detection, Multiple Models, Statistical Time-Series Methods, PCA, Machine Learning, SVM, 1D CNN

ACCELEROMETER FAULT DETECTION AND CHARACTERIZATION VIA ROBUST STATISTICAL TIME SERIES METHODS IN A COMPOSITE BEAM UNDER ASSEMBLY UNCERTAINTY

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ABSTRACT

Accelerometer signal validity constitutes a critical factor in structural health monitoring. However, accelerometer faults can compromise the reliability of the acquired data, ultimately affecting decision-making processes regarding the structural condition of the monitored system. The main objective of this thesis is to experimentally evaluate the detection and characterization capabilities of robust statistical time series methods, focusing on three magnitudes of three common types of sensor faults: bias, gain, and precision degradation, on a composite-material beam, under assembly-induced uncertainty and irrespectively of its structural condition (healthy or damaged). The robust statistical time series methods utilize data from three accelerometers, positioned along the beam, forming two pairs. The detection and characterization processes of the bias and the gain cases are based on indices that derive from the parametric representation of the Transmittance Function, using Single–Input Single–Output AutoRegressive models with eXogenous input (SISO-TF-ARX). For the precision degradation case, the non-parametric estimation of the Single–Input Single–Output (SISO) Coherence Function is employed. Their performance, assessed using the recall metric and ROC curves, derives from 1100 signals, 200 under healthy and 900 under faulty sensor state, demonstrating high performance during both (97.5% recall accuracy under healthy and 89% recall accuracy under faulty sensor state), for all three fault types and irregardless of the fault's magnitude and the beam's structural condition. Specifically, the gain and precision degradation faults were detected and characterized with almost 100% accuracy across all tests and sensors. On the other hand, for the bias case, detection accuracy was slightly lower: 75% for the two bigger magnitudes of the particular fault type, and 49% for the smaller magnitude.

Finally, the results indicated that it was easier for the bias fault to be detected in two out of the three sensors.

Keywords

Sensor Fault Detection and Characterization, Accelerometer Faults, Assembly Uncertainty, Robust Statistical Time Series Methods, Bias, Gain, Precision Degradation

INTERLAYER DWELL TIME INVESTIGATION OF THE WIRE-LASER DIRECTED ENERGY DEPOSITION ADDITIVE MANUFACTURING PROCESS THROUGH SIMULATION

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ABSTRACT

Additive manufacturing is a rapidly evolving field of modern industrial production, offering new possibilities for manufacturing parts with complex geometry in a shorter time than traditional methods. Among the individual technologies, the Directed Energy Deposition (DED) process stands out for its ability to repair or fabricate quality metal parts rapidly without dimensional limitations. It can be utilized with either powder melting or wire melting (WLDED). More specifically, the wire option gives advantages such as reduced costs, increased purity, and fewer defects. However, challenges remain regarding the full understanding of the thermal behavior during the process, particularly with respect to the Interlayer Dwell Time (IDT). This factor directly affects the cooling between successive layers and consequently the melt pool area geometry, which leads to heat accumulation and ultimately to deformation of the part geometry.

This paper develops a numerical model in MATLAB, which simulates the thermal evolution of the WLDED process in two dimensions. The model incorporates temperature-dependent material properties, realistic heat losses, and dynamic layer addition. The model within the thesis is verified both numerically using Ansys and experimentally through available studies. During the implementation of the investigation, various combinations of geometric parameters, such as the length of the part and the thickness of the deposited layer, with the residence time between layers are considered, aiming to understand the geometry of the melt pool as the layers increase and how it ultimately affects the final shape of the part. The results demonstrate that increasing the IDT helps to reduce heat accumulation and stabilize the melt pool, while the length of the part and layer thickness seem to determine the degree of IDT effect on the process. An index called, Thermal Stability Index (TSF) is also introduced, which

proves to be particularly useful in detecting areas of heat accumulation. This index could be utilized as a basis for future adaptive control strategies, enabling real-time IDT adjustment.

The thesis contributes to the understanding of Interlayer Dwell Time and its effect on the WLDED process, while also providing a tool for the optimization of critical process parameters.

Keywords

Additive Manufacturing - WLDED - Thermal Simulation - Interlayer Dwell Time -Melt Pool - Heat Accumulation

ANALYSIS OF INDICATORS FOR SUSTAINABILITY ASSESSMENT OF AN AMMONIA FUEL SYSTEM FOR A BULK CARRIER VESSEL

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ABSTRACT

The maritime sector faces increasing regulatory pressure to decarbonize while preserving operational viability and social responsibility. This thesis presents a comprehensive, multi-pillar framework for assessing the sustainability of marine fuel and storage system alternatives, with a particular focus on ammonia-based solutions. To support robust decision-making under these competing demands, this work develops and implements a structured indicator set and a hybrid Multi-Criteria Decision Making (MCDM) methodology that integrates circular economy, environmental, economic, performance and social-impact aspects. The research objective is to create a transparent, reproductive assessment framework that can quantify trade-offs between conventional heavy fuel oil (HFO) and multiple ammonia-based fuel alternatives (brown ammonia from coal and LNG, blue ammonia variants, and green ammonia) and to test the framework's robustness through scenario analysis and sensitivity testing.

The framework's core comprises of a set of tailored KPIs drawn from life-cycle assessment, circular-economy principles and maritime social-impact literature. Moreover, an Analytic Hierarchy Process (AHP) procedure is implemented, to derive importance weights under alternate policy and prioritization assumptions as well as two complementary ranking techniques (a Weighted Sum Model (WSM) and TOPSIS), to compute and validate alternative rankings.

The KPI set includes technical and intrinsic fuel properties, environmental midpoint indicators, cost metrics, performance-readiness metrics and social indicators. Indicators were normalized and implemented in a parametric spreadsheet model that makes the evaluation repeatable and transparent.

To evaluate how stakeholder priorities shape outcomes, five AHP weighting scenarios were defined, prioritizing different sustainability pillars. The model was applied to six alternative vessel–fuel configurations, producing full rankings and index values for each scenario using both WSM and TOPSIS. Results indicate consistent structural agreement between WSM and TOPSIS in many cases, but also scenario-dependent ranking shifts, especially where cost or performance is strongly prioritized, demonstrating the model's sensitivity to stakeholder preferences.

Lastly, a sensitivity analysis is conducted, intended to evaluate the framework against realistic mid and long-term sector developments (2030, 2040, and 2050). Reasonable future trajectories were compiled from industry roadmaps and literature and then translated into KPI variations in the spreadsheet model. The sensitivity exercise confirms that technology and infrastructure scale-up and gradually increase the competitiveness of ammonia options, while cost dynamics remain decisive levers in short to medium-term adoption.

The framework is deliberately modular: additional fuels, ship types, or updated KPIs can be plugged into the parametric spreadsheet developed within this thesis, for future studies. The findings underline that policy incentives (e.g. carbon pricing, targeted infrastructure investment), technology maturation (TRLs), and reductions in green-ammonia production costs will jointly determine whether ammonia becomes a widespread, sustainable marine fuel.

Keywords

maritime sustainability, ammonia fuel, indicators, assessment, bulk carrier vessel

BIO-INSPIRED ARTICULATED MECHANISM FOR CONFINED SPACE INDUSTRIAL APPLICATIONS

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ABSTRACT

Industrial automation has played a pivotal role towards the improvement of productivity, efficiency, working conditions, ergonomics and reduction of health hazards. While a large portion of industrial sectors and processes have or can be automated, certain domains serve as unexplored ground. The complexity of the processes to be executed, size and material properties of the parts of interest and available space, highlight the need for new automation technology. In this thesis, a systematic classification of product complexity and common industrial processes versus the use of conventional and bio-inspired robots is presented, aiming to identify the benefits of such robots over their conventional competitors. Moreover, a novel cable-driven snake robot design is presented and developed, featuring a modular lightweight structure of several segments, each of them controlled by a 3-cable mechanism, providing them 2 degrees-of-freedom. It exhibits significant potential to demonstrate high levels of versatility in navigating inside intricate, confined environments and narrow passages, such as aircraft fuel tanks, enabling automation of unhealthy processes that traditionally require human intervention. For the validation of the proposed approach, a case study under a real industrial environment is presented.

Keywords

Snake robot; Manufacturing; Mechatronics

DIVISION OF ENERGY, AERONAUTICS AND ENVERONMENT (SEPTEMBER 2025)

INVESTIGATION OF STABILIZATION OF HYDROGEN MIXTURE TURBULENT FLAMES IN A BLUFF BODY BY SOLVING NAVIER-STOKES EQUATIONS WITH REYNOLDS AVERAGING (RANS) AND THE PARTIALLY PREMIXED COMBUSTION MODEL USING FLAMELET-GENERATED MANIFOLD (FGM)

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ABSTRACT

This study investigates the stabilization of turbulent flames for hydrogen – ammonia mixtures on a solid annular body, with particular emphasis given on the FGM (Flamelet Generated Manifolds) and RANS (Reynolds–Averaged Navier–Stokes) models which we use to model the simulations.

Through a comprehensive literature review, we delve into the fundamental concepts and properties governing combustion and outline the steps for its complete study in modern computational environments. The computational simulations are implemented in the Ansys Fluent software and refer to mixtures with a volume content of ammonia of 0%, 25%, 50% and 72%. The results of the four cases were then compared with the experimental and computational data in the literature in order to perform a prismatic check of the validity and accuracy of the turbulence and chemical kinetics models used.

With this process, we can accurately predict the response of combustion systems and propose necessary modifications to achieve a more sustainable and efficient combustion process.

Keywords

Combustion Modeling, RANS, FGM, Flame Stabilization, Sustainable Combustion

STUDY OF SOIL TEMPERATURE ON THE SURFACE AND AT SHALLOW DEPTHS FOR ENERGY APPLICATIONS

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ABSTRACT

This thesis examines the soil temperature distribution at the surface and at shallow depths for energy applications. In the Literature Review (Chapters 1-4), the use of soil as a cooling medium is approached. How soil temperature is influenced, why prediction models are useful, what the most important prediction models are and what their applications are, are the most important points addressed. In the Methodology and Results (Chapter 5), two sets of data are analyzed and it is examined whether they match the values given by a prediction model.

In the first chapter, the use of soil as a cooling medium is analyzed, studying both direct cooling through underground buildings, which use the ground for natural temperature regulation, and indirect cooling through ground-air heat exchangers, where the air temperature is regulated with the help of the ground before entering the building.

The second chapter analyzes the soil temperature profile, focusing on the differentiation of factors that affect the surface temperature of the soil in relation to the temperature at various depths.

In the third chapter, soil temperature prediction models are presented, which estimate the surface temperature and the temperature at various depths. These models are based on various parameters, such as the thermo-physical characteristics of the soil.

In the fourth chapter, the applications of soil temperature prediction models in the energy design of buildings and other sectors are presented. Specifically, it analyzes how these predictions affect the design parameters of systems and, consequently, their optimization.

In the fifth chapter, two datasets are processed. The first set pertains to Ioannina, and the second concerns the National Observatory of Athens. A comparison is made between the experimental field measurements and the Kusuda–Bean model, using the Mean Absolute Error (MAE) and the Root Mean Square Error (RMSE). In general, the model provides satisfactory predictions in both cases. The RMSE for the Ioannina data ranges from 0.72 to 1.02, and for the National Observatory of Athens data, it ranges from 2.35 to 3.64.

Keywords

Ground Cooling, Earth-Sheltered Buildings, Earth to Air Heat Exchanger, Soil Temperature Distribution

ENERGY STUDY OF GREENHOUSE FARMING OF VEGETABLE CROPS EVALUATION

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ABSTRACT

The growing emphasis on sustainable agriculture and energy efficiency has pushed the greenhouse industry to the forefront of innovative environmental practices. This thesis, "Energy Analysis of a Greenhouse Plant", explores the multifaceted aspects of energy consumption in greenhouse operations. It provides a detailed historical context, defines the key parameters affecting energy use, and evaluates different types of greenhouses to identify the most efficient structures. The research focuses particularly on the European Union, examining its legislative framework and its practical applications. The study includes a thorough methodology for calculating cooling heat loads and energy requirements, with detailed data tables supporting the analysis. It evaluates the effectiveness of different energy efficiency strategies to optimise greenhouse operation and reduce costs. The findings show that significant energy savings can be achieved through strategic improvements in insulation, renewable energy integration and advanced climate control systems. Economic analysis reveals that energy efficient practices not only reduce operating costs but also improve profitability, creating a strong incentive for greenhouse operators to adopt sustainable practices. The thesis concludes with recommendations for future research, highlighting the potential of emerging technologies to further revolutionize energy management in greenhouses. Overall, this thesis demonstrates that sustainable energy practices are vital to the future of the greenhouse industry, offering both environmental benefits and economic advantages.

Keywords

Energy, efficiency, greenhouse, measurements

COMPUTATIONAL STUDY OF THE EFFECT ON THE FLOW AND THERMAL FIELD IN A TUBE OF RECTANGULAR CROSS-SECTION OF A VORTEX GENERATOR (VG) OF PLATE TYPE WITH TWO HOLES OF DIFFERENT DIAMETERS AND FOR DIFFERENT PLATE ANGLE OF ATTACK AND REYNOLDS NUMBER

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ABSTRACT

The subject of the present diploma thesis is the investigation of the effect of a flat tile type vortex generator with two holes in the flow and thermal field of a heated tube with rectangular cross-section. Air flows inside the tube. To investigate the effect of the tile we apply different values to the diameters of the holes, different angle of attack as well as Reynolds numbers at the entrance of the tube. Our aim is to improve heat transfer and achieve low pressure losses.

First of all, the basic theoretical background of fluid mechanics (e.g. flow categories, boundary layer analysis), the heat transfer mechanisms as well as the characteristics of vortex generators and their use for heat transfer are presented. In addition, an introduction to computational fluid dynamics is given using ANSYS FLUENT.

Then the geometries of the problem were designed and after the completion of the discretization through the application of an appropriate mesh, the parameters of the simulations were adjusted.

Initially, a test was performed for different values of tile hole diameter (for VG without holes and for D=2,4,6 mm), with the same diameter applied to both holes, and at the entrance of the tube Reynolds 10000 and the optimal diameter was selected. Then this optimal diameter was investigated for different Reynolds values at the tube inlet (5000,10000,15000,25000). To understand the effect of the vortex generator a comparison was made between a similar empty conductor with the same Reynolds values at the inlet. Simulations were then followed for the optimum diameter tile for angles of attack (0,20,45,60,85 degrees). The angle of attack that showed the best results was compared to the empty tube for various Reynolds values. The average outlet temperature in the pipeline, Nusselt number, and pressure drop coefficient were calculated.

Finally, we conclude that the use of vortex generators is optimal when they are placed at a certain angle of attack. Also, for different Reynolds numbers there is an increase in the Nusselt number while the exit temperature and the Darcy pressure factor decrease.

Keywords

Heat transfer, Reynolds, Vortex Generator, Fluent, Pressure drop, angle of attack

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING ORTHOGONAL VENTS OF HEAVY TYPE WITH FIXED VANES OF ONE DIRECTION SUITABLE FOR IN AND OUT VENTILATION AND FOR PLACEMENT ON THE FLOOR

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ABSTRACT

This thesis focuses on the study of air flow through orifices in a defined space, in order to understand and evaluate the basic characteristics of the flow. The main variables considered are air exit velocity, air velocity range, lift, settling, diffusion, noise levels as well as pressure drop. As part of the study, the air flow through the LH1 400x200 grille was analyzed to understand the flow behavior under different conditions. As a basic parameter, the air exit velocity from the grille was set to not exceed 10 m/s, while in the flow field of interest, the target velocity for comfort conditions was set equal to 0.5 m/s. These values were used as a reference for evaluating the performance of the air distribution system and analyzing the velocity attenuation in space. For this purpose, two turbulent flow models, k-ε and k-ω, were used and implemented in the ANSYS Fluent computational environment. Through the simulations, the performance of each model was evaluated in terms of calculating key flow characteristics. In addition, the effect of the air temperature was investigated by performing analyses for three different values: 295 K, 300 K and 305 K. These variations allowed to study the thermal effect on the flow, as well as to compare the results under different thermodynamic conditions. By combining the two turbulence models and the three thermoclines, the two turbulence models and the three thermoclines were combined.

Keywords

Computational Fluid Dynamics, Air Flow, Turbulence Model, Vents, Main Variables

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD FROM AIR-CONDITIONING VENTS WITH GRILLES OF SLOT TYPE WITH MANUAL REGULATED DUMPERS OF THREE POSITIONS FOR DIFFERENT TEMPERATURES OF THE SUPPLIED AIR

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ABSTRACT

The purpose of this thesis is the study of airflow entering a space of predefined dimensions through grilles/outlets and the analysis of the fundamental flow characteristics. Parameters such as outlet air velocity, throw, rise, drop, spread, pressure drop, and noise level are examined, aiming to understand the behavior of air within the interior space and its correlation with thermal comfort conditions. The methodology includes extracting geometric models from SOLIDWORKS, meshing the geometry into discrete elements, and analyzing the flow through computational fluid dynamics (CFD) using ANSYS FLUENT. The calculations were carried out for the slot-type grilles STP.V1R 10 and STP.V1R 20, which can direct the airflow upward, horizontally, or downward through adjustable vanes within the grilles. Additionally, an analysis was conducted under various thermal conditions to evaluate performance under real operating scenarios. The maximum airflow rate was determined based on the maximum permissible outlet velocity of 10 m/s, while the region of interest was defined as the zone where the air velocity is limited to 0.5 m/s, ensuring thermal comfort conditions for the occupants within the space.

Keywords

Grilles, Airflow, Computational Fluid Dynamics, Air Conditioning, Thermal Comfort

COMPUTATIONAL INVESTIGATION OF CARACTERISTSICS OF AMMONIA-AIR AND AMMONIA-HYDROGEN-AIR MIXTURES IN LAMINAR FLAMES

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ABSTRACT

Climate change stands as one of the most pressing challenges of modern humanity, driven largely by the continuous increase of carbon dioxide (CO_2) emissions from fossil fuel combustion. These emissions intensify the greenhouse effect, raising global temperatures to levels that threaten ecosystems and human well-being. Significant efforts have been directed towards sustainable alternative fuels capable of reducing carbon footprints and mitigating environmental damage. Among the most promising options are ammonia (NH_3) and hydrogen (H_2) both of which deliver clean energy with minimal carbon emissions. Hydrogen possesses high energy content and clean combustion characteristics, producing only water vapor. Nevertheless, its storage and transport are hindered by high volatility and the need for extreme conditions, while its production requires substantial electrical energy that may not always originate from renewable sources. Conversely, ammonia is easier to transport and store under moderate conditions while it does not release CO_2 during combustion. On the other hand, it faces challenges such as high ignition temperatures, low flame speed and increases NO_x emissions. The study is structured in two main parts. The first part presents a literature review summarizing the physicochemical properties of the two fuels, their interaction in mixtures, and recent research trends in the field of alternative fuel combustion. In the second part, CHEMKIN PRO software is employed to simulate combustion processes using nine different, validated chemical kinetic mechanisms. The analysis focuses on laminar flame speed, ignition delay time, and NO_x emissions across a wide range of equivalence ratios and preheat temperatures. The reliability of the computational predictions is assessed through comparison with experimental data from recent international studies, enabling the identification of the most suitable kinetic mechanism for predictive and optimization purposes. The findings are expected to contribute to a deeper understanding of NH_3–H_2

mixture combustion and to support the development of zero-emission technologies in state-of-the-art energy applications.

Keywords

climate change, ammonia (NH_3), hydrogen (H_2), sustainable fuels, emissions, carbon footprint.

NUMERICAL INVESTIGATION OF THE EFFECT OF CAVITIES (SURFACE PROTRUSIONS) ON MODIFIED U-SHAPED DUCT WALL OF VARIOUS DIAMETERS AND PATTERNS, ON THERMAL AND FLOW FIELDS, FOR LAMINAR AND TURBULENT CONDITIONS

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ABSTRACT

Modification of a duct's walls is a highly effective method for enhancing heat transfer in the fluid flowing through it. Despite the extensive literature on applications involving straight ducts, studies focusing on curved ducts are relatively limited. In this context, the present study models nine different configurations of modified walls in a U-shaped curved duct, using hemispherical cavities. The analysis was conducted within the computational environment of ANSYS Fluent, covering a wide range of Reynolds numbers, including laminar, transitional, and turbulent flow conditions, under constant wall temperature and uniform inlet fluid temperature.

In the first part of the study, the fundamental theoretical concepts of fluid mechanics and heat transfer are presented. Various heat transfer enhancement techniques are discussed, with special emphasis on vortex generators. Curved ducts are analyzed in detail, highlighting the specific characteristics and flow phenomena associated with them. Finally, an introduction to the ANSYS Fluent environment is provided.

The main part of the study describes the entire process of geometry design, discretization, computational validation, and model simulation. Initial conditions, selected materials, turbulence models, Reynolds numbers, and solution methods are all specified.

The simulation results are presented through diagrams and tables. It is observed that the use of cavities on the duct walls significantly improves heat transfer to the working fluid. However, the results also show an increased pressure drop, compared to a smooth-walled duct.

In conclusion, the performance of the cavities is most effective in the laminar flow regime and reaches its peak in the transitional range. In turbulent flow, the enhancement is lower, but still notable, in some models. Nevertheless, the use of wall cavities holds promise for even greater performance and warrants further investigation.

Keywords

Curved pipes, Heat transfer enhancement, Vortex generators, Cavities (Surface protrusions), Computational fluid mechanics.

ENERGY EFFICIENCY UPGRADE OF A PUBLIC SPORTS FACILITY: A CASE STUDY OF THE INDOOR GYMNASIUM IN KERATSINI

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ABSTRACT

This thesis investigates the optimal method for detecting artificial damage scenarios in a standard model with four degrees of freedom (4-DOF), based on oscillation acceleration signals. The significance of the topic studied is high, as the timely detection of damage in a structure is directly related to its efficiency and the safety of the user. The monitoring of the structural integrity of constructions is achieved through the study of their dynamic characteristics. The signals collected from an accelerometer and analyzed both non-parametrically, using the Welch method, and parametrically, using autoregressive (AR) models, to identify the individual dynamic characteristics of the system.

The effect of nine artificial failure scenarios on the model's dynamics is then studied, considering the uncertainties due to changing environmental operating conditions and factory inaccuracies. Specifically, three types of damage are examined, which result in a reduction in the stiffness constant of one of the three springs of the structure, by 7, 14 and 24%. For the modeling of uncertainties, a homogeneous healthy population with 200 structural elements and nine damaged populations (one for each damage scenario) consisting of 100 elements each, which give a total of 1100 response signals.

The structural integrity diagnosis process is divided into three stages: (1) damage detection, (2) damage localization and (3) damage severity. The damage detection is performed using three different methods, one unsupervised (U-MM-AR) and two supervised (SVM and 1D CNN), which are then enhanced using PCA transformation. The results highlight on one hand the effectiveness of the PCA transformation in reducing the impact of uncertainties and on the other hand the efficiency of supervised methods, and particularly the SVM algorithm in fault detection. Subsequently, an attempt is made to classify damage through the detection of their location and size, with PCA-enhanced 1D CNN achieving better performance. The results are evaluated using Confusion Matrices and ROC Curves.

Keywords

AR, Varying Environmental and Operating Conditions, Uncertainties, Population, Damage Detection, Multiple Models, Statistical Time-Series Methods, PCA, Machine Learning, SVM, 1D CNN

COMPUTATIONAL INVESTIGATION OF THE AIR FLOW FROM LINEAR GRILLES WITH REGULATING DAMPER OF THE FLOW DIRECTION FOR DIFFERENT TURBULENCE MODELS

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ABSTRACT

Air conditioning constitutes a key field within fluid mechanics, as it is directly linked not only to human comfort (particularly thermal comfort) but also, and more critically, to human health. The proper design and operation of an air conditioning system require thorough studies by engineers, aiming to provide sufficient and high-quality ventilation while maintaining conditions of thermal comfort. The study of the airflow field within a space is of particular importance, as it reveals the distribution of air, the adequacy of ventilation, and the prevailing local conditions. Nowadays, such studies are predominantly conducted using Computational Fluid Dynamics (CFD), a scientific method that numerically solves the equations govering fluid flow by utilizing computational resources.

This diploma thesis investigates the airflow generated by slot-type air conditioning diffusers equipped with grilles and a flow-regulating slider. The study is conducted within the laboratory space of the Fluid Mechanics Laboratory at the University of Patras. The objective is to determine the characteristic flow parameters under various operating conditions, to compare three different turbulence models for all conditions, and to evaluate the performance of these specific grilles. The simulation and analysis of the flow phenomena were carried out using the Ansys Fluent software.

Keywords

Thermal comfort, CFD, air conditioning, grilles, Ansys Fluent

COMPUTATIONAL SIMULATION OF AIR FLOW FIELD IN ORDER TO DETETRMINE THE TECHNICAL CHARACTERISTICS OF THE FLOW FROM AIR-CONDITIONING ORTHOGONAL VENTS WITH PLANE AND CURVED GUIDE VANES OF VARIOUS DIRECTIONS

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ABSTRACT

In this thesis, Computational Fluid Dynamics (CFD) methods are employed to determine the technical characteristics of air jets in HVAC applications. Specifically, isothermal jets produced by different air supply grilles are examined in order to determine the throw, spread, rise, and drop of the jet corresponding to the 0.5 m/s velocity envelope. Simultaneously, the pressure drop at the air supply outlet is determined for the calculation of the generated noise. Additionally, regression analysis is performed to determine the same parameters for airflow rates that were not directly simulated. For further insight, visualizations are produced showing the shape of various velocity envelopes, the velocity and pressure fields at selected planes, and the airflow streamlines. The above are carried out through computational simulation using the ANSYS FLUENT software. The computational simulation employs the finite volume method on an automatically generated tetrahedral or polyhedral mesh and is evaluated through a grid-independence study combined with the assessment of the mesh quality metrics. Turbulence is modeled using the k–ω SST model, the solution is obtained using the SIMPLE algorithm, and second-order discretization schemes are applied. A command file is also developed for the automation and rapid modification, enhancement or repetition of the procedure, as well as for instant data collection and processing. Finally, the convergence and quality of the simulation are assessed based on the residuals of the equations, the monitoring of the variation of the computed quantities with respect to the iterations, the calculation of the mass imbalance within the computational domain, and visual inspection.

Keywords

HVAC, CFD, ANSYS FLUENT, Air Jet, Intake Grille

NUMERICAL IMPLEMENTATION OF ONE - DIMENSIONAL ADAPTIVE MESH USING THE FINITE VOLUME METHOD

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ABSTRACT

In computational fluid dynamics, there are problems that do not require uniform accuracy in the mesh. The solution becomes much faster when the mesh is denser in areas that require greater accuracy. However, these areas are not always the same, so a dynamic mesh refinement technique is required, which is called an adaptive mesh. In this paper, a one-dimensional mesh that follows a source will be implemented using the MATLAB program. First, basic concepts of Computational Methods in Partial Differential Equations (PDEs) are explained, starting with the finite difference method and ending with the finite volume method. Next, the mathematical relations governing the phenomenon of transport and diffusion in the context of finite volumes are presented, which will also be applied in the code that will be implemented. As for the mesh, the procedure to be followed is to create a mesh that will thicken at one end and join two such meshes at a point of our choice. The dynamic adjustment of the mesh will be performed by recalculating the cells after each iteration based on the position of the source, which will move during the application. Next, we will connect the code of the adaptive mesh with a code that solves the transport and diffusion equation with a moving source, where we will observe the change in the solution at various positions of the source term and the mesh following the source, just as we wanted. Finally, we will compare the adaptive mesh with a uniform one to examine its correctness and compare various numerical convection schemes with each other.

Keywords

Numerical Analysis, Partial Differential Equations, Mesh Refinement, Dynamic Mesh Adaptation, Remeshing and Mesh Update

ABSORPTION REFTIGERATION CYCLE - DESIGN AND SIZING

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ABSTRACT

This paper focuses on the study and evaluation of solar cooling through an absorption refrigeration cycle, with a primary emphasis on modeling and dimensioning the cycle with an H_2O/LiBr pair. The introductory chapters analyze the fundamental principles of solar cooling and present absorption and adsorption technologies, as well as their comparative advantages. In addition, the various types of solar collectors are examined, as well as the factors that determine their selection, given the critical importance of efficient utilization of solar radiation.

The second part describes the basic components of the absorption cycle, namely the absorber, generator, evaporator, condenser, and expansion valve. Particular emphasis is given to the analysis of the NH_3/H_2O and H_2O/LiBr working fluid pairs. The first pair is found to be the most suitable for refrigeration applications, while the second has more benefits in air conditioning.

The third chapter constitutes the main focus of the study, as it develops the modeling of the absorption cycle with the H_2O/LiBr pair using MATLAB software. Mass and energy balances are formulated for each individual component, while appropriate assumptions are adopted to simplify the analysis without loss of accuracy. The coefficient of performance (COP) is calculated based on thermal balances, allowing comparison with theoretical values and bibliographic data. The results present the necessary parameters for designing the desired air conditioning system according to the needs of the user.

The fourth chapter summarizes the conclusions of the research. Solar cooling with an H_2O/LiBr absorption cycle emerges as a reliable, energy-efficient, and environmentally sustainable technology. The modeling confirms that, with proper dimensioning of the individual components, stable operation with satisfactory COP is achieved, making the system competitive with conventional technologies. Therefore, its application can contribute

significantly to reducing primary energy consumption and limiting emissions, enhancing the integration of renewable energy sources in the refrigeration field.

Keywords

Refrigeration cycle, Absorption, Working pairs, Modeling, Sizing

SIMULATION OF A HYBRID PHOTOVOLTAIC /THERMAL SYSTEM (PV/T)

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ABSTRACT

For the last decades, owing to the high increase of gas emissions and the greenhouse effect, there has been a strong shift towards more sustainable energy production, especially through the utilization of renewable energy sources. To take advantage of those, there has been a development of many types of systems, like hydroelectric power stations, wind farms and photovoltaic systems. A new highly promising system is the hybrid photovoltaic thermal (PV-T) collector. These types of collectors combine a photovoltaic system with a thermal absorber for the simultaneous production of electric and thermal energy. In this way, the photovoltaic panel's efficiency, which is dependent on temperature, is increased and the recovered thermal energy can be utilized for various applications. Initially, there will be a presentation of the several types of such collectors, modifications for their optimization and some of their applications such as water heating, air heating and solar desalination. In this thesis, the thermal performance of a PV-T collector installed near Patras has been studied. For the system's simulation, the TRNSYS 18 software has been used. The electric part was ignored as the emphasis was given mainly on the thermal performance. For a tank volume of 300 L, three different 4, 6 and 8 m2 collector area surfaces were evaluated, in order to find which ratio of tank volume to PV area (37.5, 50, or 75 L/m^2) is most suitable for an installation near Patras. The fluid flow rate used for the PV cell cooling was adjusted from 0.02 to 0.025 and then to 0.03 to check the tank's response to different flow rates. The system's function was evaluated in four different months. The testing periods were 24-26 January, 13-15 April, 13-15 July and 3-5 October as they were considered representative periods of each season. As a result, in the last part of the thesis, the temperature charts and the conclusion about which one is the most ideal solar tank for each season, are presented.

Keywords

PV-T collectors, photovoltaics, thermal collectors, RES, energy

ENERGY STUDY WITH HEAT PUMP AND ASSISTED BY RENEWABLE SOURCES

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ABSTRACT

This thesis investigates the energy renovation of a single-family house in Ioannina through the installation of a heat pump and other modern technologies, aiming at reducing both energy consumption and the building's environmental footprint. Initially, the dwelling suffered from significant thermal losses and relied on an oil boiler, leading to high operating expenses and increased greenhouse gas emissions. The implementation of thermal insulation measures, combined with the replacement of the old heating system by a heat pump, resulted in a substantial reduction of heating demand and improved overall efficiency. Furthermore, a photovoltaic system with energy storage was integrated in order to cover the household's electricity needs under a net metering scheme. This intervention ensured almost complete elimination of electricity bills, enhanced energy independence, and provided long-term financial sustainability. The investment analysis demonstrated a short payback period and positive performance indicators, confirming the project's viability. In parallel, the environmental impact is particularly significant. The drastic reduction in fossil fuel consumption and the substitution with clean electricity substantially lowered CO_2 emissions, while also mitigating the problem of wintertime smog, which severely affects air quality in Ioannina. Overall, the findings of this thesis highlight that the combination of heat pumps, thermal insulation, and photovoltaic systems represents a comprehensive and sustainable solution for the energy renovation of residential buildings. Such interventions generate tangible economic benefits for homeowners, reduce the environmental footprint of the housing sector, and contribute to the broader goals of sustainable development and climate change mitigation.

Keywords

Heat pump, photovoltaic system, building energy renovation, energy production, thermal losses.

DIVISION OF MANAGEMENT AND ORGANIZATION (SEPTEMBER 2025)

ADDRESSING DATA IMBALANCE IN PREDICTIVE MAINTENANCE: A PERFORMANCE EVALUATION OF GENERATIVE ADVERSARIAL NETWORKS (GANs) FOR SYNTHETIC DATA GENERATION

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ABSTRACT

Predictive maintenance (PdM) systems must infer rare failure events from predominantly healthy operation, a setting where naive accuracy obscures risk and data scarcity undermines learning. This thesis develops and tests a theoretical and methodological groundwork for evaluating synthetic oversampling with generative adversarial networks (GANs) in high-imbalance PdM classification. This study aims to construct a comparative framework for machine failure classification with the use of 2 models, Random Forest and Support Vector Machine, under five sampling techniques: (i) baseline with stratified cross-validation, (ii) random undersampling, (iii) SMOTE, (iv) a single WGAN-GP synthesizing failures, and (v) a multi-WGAN-GP strategy that specializes generation by failure subtype. The pipeline formalizes leakage-safe preprocessing (feature typing/encoding, scaling and distributional transforms appropriate for margin-based models, and outlier handling that preserves minority boundaries), with all fitting confined within folds. The study finds that GAN Hyperparameter tuning and correct model evaluation play an important role and suggests bayesian optimization solutions like Optuna's TPE sampler, as well as the use of PR-AUC as the primary metric for imbalanced classification. Complement metrics like ROC-AUC recall at fixed false-positive rates may also be used to reflect operational trade-offs in PdM. The study examines the types of GAN variations with the aim of with the aim of avoiding the usual training problems, mode collapse and vanishing gradients, and articulates when subtype-specific generators can better capture heterogeneous failure modes. Finally, the use of t-SNE visual diagnostics is examined to assess manifold coverage and boundary fidelity of synthetic samples. The findings of this study suggest that type-sensitive GAN oversampling can be a great solution for synthetic oversampling in PdM.

Keywords

Predictive Maintenance, Imbalanced Classification, Synthetic oversampling, WGANGP, Imbalanced performance evaluation

PREDICTING STOCK PRICE REACTIONS BASED ON NEWS ANALYSIS

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ABSTRACT

This study examines the relationship between news articles and the short-term fluctuations in the prices of the stocks to which they refer. Initially, a corpus of news articles related to selected stocks is collected from the New York Times. Subsequently, sentiment analysis is applied to the texts using the FinBERT model. At the same time, stock price data are retrieved from investing.com. These data, combined with the sentiment analysis results, are processed through a suitably designed algorithm in the Python programming language and imported into an Excel file, where additional calculations are performed in order to derive a final success rate. This rate expresses the probability that the sentiment of the news aligns with the stock's price movement on a given day. The term "alignment" refers to the case in which negative news corresponds to a negative price change, while positive news corresponds to a positive price change. The study focuses on three stocks: Amazon, Microsoft, and Tesla. The observed success rates were 55.5%, 68.8%, and 58.8%, respectively. These results are considered satisfactory, as they reveal an advantage ranging from 5.5% to 18.8% compared to randomness (50%), given that only two possible outcomes exist (positive or negative). Therefore, it can be concluded that news articles are associated with stock price movements and, in several cases, exert an influence on them. This finding suggests that it is worthwhile for investors to take news sentiment into account. Nevertheless, it must be emphasized that financial markets are inherently multifactorial, and their analysis cannot be confined solely to the dimension of news sentiment.

Keywords

News, sentiment analysis, stock market, FINBERT model

ANALYSIS AND DESIGN OF A HUMAN RESOURCES MANAGEMENT INFORMATION SYSTEM

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ABSTRACT

This thesis focuses on the study, analysis, and design of a Human Resource Information System for Helleniq Energy. Initially, it presents the functions of the human resources department and highlights the importance of artificial intelligence and information systems in enhancing these operations. Subsequently, it describes information technologies that contribute to human resource management, emphasizing the candidate classification process, cloud computing, big data, and the use of digital assistants. It then analyzes the existing human resource information systems at Helleniq Energy, identifying their weaknesses and shortcomings. Finally, the thesis concludes with a comprehensive analysis and development of a new system featuring additional capabilities such as automated approval workflows, full coverage of the candidate selection process, and real-time monitoring of data and visual representations using critical indicators. The system analysis includes documentation of functional and non-functional requirements, user stories, use case diagrams, data flow diagrams, entity-relationship diagrams, and the rapid prototyping process. In summary, the thesis demonstrates that digital technologies can serve as valuable tools in human resource management, provided they are designed with a user-centric approach that addresses users' needs.

Keywords

Information Systems, Human Resource Management, Artificial Intelligence, Digital Assistants, Digital Transformation

APPLICATIONS OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN THE ENERGY SECTOR

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ABSTRACT

This thesis investigates how Artificial Intelligence (AI) and Machine Learning (ML) are changing the recent energy landscape with respect to sustainability, efficiency, and innovation. The paper starts by setting the scene for the global transition to energy and the digital transformation powered by AI. It examines the core ideas and techniques of AI/ML before looking in detail at how they can be applied in practice along the energy value chain — from energy sources and distribution to consumption and demand management. Core chapters demonstrate how AI improves the integration and control of renewable energy sources (RES) including solar and wind power by embracing more accurate prediction and dynamic encryption. The contribution of smart grids and microgrids is emphasized, especially for the fault detection, predictive maintenance, and the real-time optimization. In energy demand, AI allows smart buildings and industries to have dynamic energy efficiency and user behavior modeling helps to realize personalized demand response.

The thesis further examines future directions including deep learning, green AI, human and machine cooperation, the block-style energy market. It also highlights pressing issues – such as data privacy, algorithmic bias, cyber-security and regulatory shortfalls – underlining the importance of ethical and inclusive regulation. The article argues that a growing theme in the energy sector is that AI and ML are not merely technical, but also crucial strategic tools for redrawing the contours of the energy map. The pace of deployment of these applications can drive the rapid transition to a low-carbon, secure and equitable energy system if the technological innovation is accompanied by institutional readiness and social inclusion.

Keywords

Artificial Intelligence, Machine Learning, Energy Transition, Smart Grids, Renewable Energy

INFORMATION TECHNOLOGIES IN AIRCRAFT MAINTENANCE

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ABSTRACT

This thesis investigates information technologies that can be effectively applied to aircraft maintenance. An aircraft is a highly complex structure, primarily mechanical in nature, that adheres to strict safety protocols from the design stage onward. Maintenance plays a vital role in ensuring its safety, functionality, and longevity. Information technologies such as Big Data, the Internet of Things (IoT), Artificial Intelligence (AI), Extended Reality (XR), Digital Twins, and Additive Manufacturing are thoroughly examined—both theoretically and through case studies of aircraft that employ these technologies in their maintenance operations. Through the analysis of these case studies, significant conclusions are drawn regarding the benefits of such technologies, while the thesis concludes with several suggestions for future research in the field of information technologies applied to aircraft maintenance.

Keywords

Aircraft Maintenance, Information Technologies, Predictive Maintenance, Artificial Intelligence, Extended Reality

DIGITAL ASSISTANTS IN THE INDUSTRY 4.0 ERA: A THEORETICAL ANALYSIS AND PRACTICAL APPLICATION

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ABSTRACT

This study focuses on the role of Industry 4.0 and the use of digital assistants (chatbots) across various sectors. It begins with a historical overview of the four industrial revolutions, emphasizing the technological advancements that have driven the transformation of economies. Special attention is given to the fourth industrial revolution, which leverages technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics to create intelligent production systems.

The study examines the concept, types, and evolution of chatbots, analyzing their transition from simple algorithms to advanced AI-based systems. Their use is highlighted in sectors such as manufacturing, supply chain management, customer support, and human resources management. Chatbots contribute to improved efficiency, cost savings, real-time data access, and the creation of personalized user experiences.

The study also addresses the challenges associated with adopting chatbots, including the need for ethical AI, privacy protection, and transparency in interactions. Future trends involve their integration with other technologies, adaptation to multilingual environments, and sustainability.

In conclusion, the study demonstrates that chatbots, as an integral part of Industry 4.0, serve as a valuable tool for digital transformation, while their widespread adoption relies on ethical and responsible usage.

Finally, beyond the theoretical analysis, the thesis also includes a practical application: the development of a maintenance chatbot supported by an SQLite database. This application serves as a pilot case study, demonstrating how theoretical concepts can be transformed into tangible tools for industrial practice, thereby enhancing the value and applicability of the research.

Keywords

Industry 4.0, Chatbots, Artificial Intelligence (AI), Digital Transformation, Personalized Support

HOUSING PRICE PREDICTION BASED ON MACHINE LEARNING TECHNIQUES

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ABSTRACT

This thesis investigates the application of modern machine learning methods to predict short-term rental prices in the Municipality of Athens, using data from Inside Airbnb. The main objectives are to document the superiority of boosting models over traditional linear approaches, to assess the contribution of feature engineering—particularly spatial and operational variables—to prediction accuracy, and to provide interpretable evidence on the key determinants of pricing. The methodology encompasses data cleaning, preprocessing, feature engineering, feature selection and hyperparameter tuning, while comparing five models: Linear Regression, Random Forests, Gradient Boosting, XGBoost, and LightGBM. Model evaluation relies on MAE, RMSE, R^2, and training time. The findings indicate that Gradient Boosting Machines consistently outperform linear baselines and single decision trees in accuracy. Model interpretability highlights location, listing type, capacity, and reviews as primary drivers. Overall, the results underscore the practical value of boosting models, when combined with careful feature engineering, for more accurate pricing of short-term rentals, and suggest directions for future research on data enrichment (text/image) and spatially aware validation.

Keywords

Price Predictions, Machine learning, Boosting Algorithms, Random Forest, Data Analysis

DEVELOPMENT OF A DIGITAL ASSISTANT FOR MANAGING STANDARD OPERATING PROCEDURES IN AN INDUSTRIAL ENVIRONMENT WITH THE USE OF LARGE LANGUAGE MODELS

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Poster: https://mead.upatras.gr/diplomatikes-spoudastikes-ergasies/?filter_8=1026406&filter_4=%CE%94%CE%B9%CF%80%CE%BB%CF%89%CE%BC%CE%B1%CF%84%CE%B9%CE%BA%CE%AE&filter_1=&filter_2=&filter_12=&mode=all#gv-view-22037-1

ABSTRACT

This diploma thesis explores the historical evolution of conversational agents (chatbots) and presents the development of a prototype Greek-language chatbot using the Google Apps Script platform and a Large Language Model (LLM). It first examines key milestones in the progression of chatbots, from early theoretical foundations in the early 20th century to modern intelligent assistants powered by advanced neural networks. Also, it provides a brief taxonomy of chatbots and discusses their representative business applications, establishing the context for the proposed solution.

The main part of the thesis focuses on the design and implementation of a conversational assistant for an industrial production environment. The proposed system, named mAI_SOP, leverages an enterprise's official Standard Operating Procedure (SOP) documents as its knowledge base, allowing production operators to pose questions in Greek and receive immediate, well-documented answers. The system was implemented as a web application on Google Apps Script, featuring an HTML/JavaScript user interface and integration with OpenAI's GPT-4.1-mini model via API for natural language understanding and generation. The chatbot's responses are returned in a structured JSON format, including step-by-step instructions, safety highlights, and citations referencing the relevant SOP sections. Additional features such as user authentication, support ticket logging, and text-to-speech output were incorporated to facilitate use of the system on the shop floor. The developed prototype demonstrates its effectiveness by providing workers with instant and reliable access to SOP knowledge, thereby reducing the time needed to find information and enhancing compliance with prescribed procedures.

Keywords

Chatbots, Large Language Models (LLMs), Google Apps Script, Standard Operating Procedures, Industrial Production