University of Patras
Department of
Mechanical Engineering and Aeronautics

<u>Diploma Thesis</u>
Academic Year
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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 2022)

DAMAGE DETECTION USING PHASED ARRAY ULTRASOUND AND DATA ANALYSIS USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

The present thesis aims to damage detection of composite aeronautical materials with the phased array ultrasonic testing (PAUT) and data analysis artificial intelligence (AI). First, there is an introduction to the source of the project's inspiration and its scientific significance. Secondly, there is a reference on composite materials, how they are used in aeronautical applications, and the damage mechanisms that take place. At that point, after briefly examining some standard non-destructive testing (NDT) methods, the selected technique and its capabilities are analyzed in depth, both at a theoretical and a scientific level. Next, the concept of Artificial Intelligence, Machine and Deep Learning is introduced, and the methods of "Supervised Learning" and "Unsupervised Learning" are analyzed in detail. More specifically, the clustering algorithm K-means and the Deep Neural Networks (DNNs) with emphasis on the convolutional neural networks (CNNs) are examined. Then, after a literature review of the scientific efforts made concerning the analysis of ultrasound data using artificial intelligence, the description of the project is presented, followed by the forming of the research questions and the methodology that was applied in the following research. Subsequently, the experimental setup (materials, equipment), the way of capturing the data, and the pre-processing and post-processing methods are described. Next, the unsupervised machine learning method used for binary classification for two different composites is analyzed, and the respective results are presented. Furthermore, the supervised deep learning method used for binary classification is analyzed, and the relevant

results are presented. Finally, the conclusions that emerge from this analysis are presented, and suggestions for improvement and expansion of the work in the future are reported.

Keywords

Damage detection, composite materials, non-destructive testing (NDT), phased array ultrasonics testing (PAUT), artificial intelligence (AI)

MANUFACTURING AND EXPERIMENTAL CHARACTERIZATION OF BIO-BASED ADHESIVE JOINTS: EFFECT OF CARBON NANOTUBE-REINFORCEMENT AND HYGROTHERMAL AGING

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ABSTRACT

The present research is a part of the general field of Materials' Science, a field that has historically occupied humanity and has evolved into Science with countless applications and ramifications.

In our century, the excessive use of mineral resources has pushed scientists in research of more ecological solutions applied in various aspects of our lives. Such efforts include the use of non-renewable energy sources (eg photovoltaic, wind power etc.) as well as the production of biodegradable products to replace hydrocarbon products (crude oil).

More specifically, in this specific research we made a study of a structural resin, which is used in constructions and micro-constructions (eg aeronautical constructions), which has decorative use too. The difference with commercial resins is that its base is organic. Thus, the resin is derived from epichloridine and cardanol and not from hydrocarbons as usual. Epichloridine is produced from glycerol which is pure in nature as a raw by-product of the hydrolysis of fats and oils, while cardanol is produced from the anacardium acid which is found in cashew oil.

In this study, reference was first made to the theory of polymers, their historical development, composition and types, and then the experiments were described. In the process of experiments, an attempt was made to optimize each process (widely, from production to the experimental process). The study began in the Student Thesis with the production of resin and then a study was made of its tensile strength with pure resin specimens and its tensile strength when reinforced with three different percentages of carbon nanotubes. The reinforcement of the adhesive resulted in an increase in the Young's

Modulus and a decrease in its tensile strength. We observed that the change in properties is proportional to the change in the content of the reinforcement.

Then, in the framework of the Diploma Thesis, an experiment was performed for the characterization of resin as a means of bonding structures based on the shear strength of the single resin coating in composite material (CFRP) and aluminum (2024-T3). Finally, the experiment of hygrothermal aging of the resin took place with the aim of characterizing its mechanical properties as well as the study of the glass transition temperature. This experients took place in order to study the flexibility of the mechanical behavior of the resin in relation to environmental conditions and aging. Thus, we applied accelerated hydrothermal aging conditions (70^{o}C / 85% RH) to the point of saturation.

Finally, in order to carry out the conclusions, the stress-strain curve was designed for each specimen separately (5 plain resin specimens and 15 specimens reinforced with three different percentages of CNTs), and also the comparison of the specimens (of each group) with each other, as well as the comparison of pure bio-resin with a commercial resin (EA9696).

The final results showed that the resin has a modulus of elasticity of 1.85 GPa, tensile strength of 60.6 MPa and a glass transition temperature of 65.1^{o}C. In addition, the shear strength of the adhesive in aluminum bonding is 6.35 MPa for the rough surface treatment and 13.64 MPa for the surface chemical treatment. The shear strength of the resin for bonding with composite material is 22.27 MPa.

The hydrothermal aging caused a decrease in the measure of elasticity, tensile strength, tension intensity coefficient and glass transition temperature of the adhesive by 13%, 35%, 3.2% and 13.8%, respectively. So we conclude that the resin is quite prone to environmental aging. Nevertheless, the application of hydrothermal aging caused an increase in the shear strength of the resin for both bonding with aluminum and bonding with the composite.

Keywords

Bio-base, adhesive, shear strength, hygro-aging, single-lap-joint experiment, Aluminium, CFRP material

TOPOLOGY OPTIMIZATION AND STRUCTURAL ANALYSIS OF A DEPLOYABLE ANTENNA OF UMBRELLA TYPE RIB FOR 3D-PRINTING

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ABSTRACT

In the first chapter of this master thesis, I will present a few basic information on satellites and how they are categorized. Afterwards, I will get into more detail about deployable structures, and more specifically the deployable reflector antenna. I will categorize the reflector antenna based on three aspects: the reflective surface type, the deployment mechanism and the antenna feed type. The advantages and uses of these categories are going to be analysed. Later, information will be given on the antenna gain, which is a vital quality as it indicates how well the conversion of radio waves to electric signals is executed, and the accuracy of the reflector. Finally, examples of materials that can be used for the reflective surface will be presented, as they need to be highly reflective to be suitable for this role. Also, materials that can be used for the deployment structure will be shown, as they must combine great behavior in space conditions, lightweight and strength.

In the second chapter, I will be focusing on the design of a rib of an umbrella type deployable antenna. First, I will present information on the topology optimisation method, and additive manufacturing in the aerospace field. Afterwards, I will present the material that will be used, its mechanical properties and how the manufacturing process affects them. Next, I will be performing static structural and modal analysis, utilising FEM, on an original design and, based on those, the rib will be topologically optimised. The objectives of the TO process will be to reduce the total rib mass and to maximise the first natural frequency. The resulting design will be validated and compared with the original one and I will be analysing how this process ends up being beneficial for the component design. At the end of the thesis, I will be giving some suggestions about possible following projects that would help in optimising the material properties and validate its structural integrity by conducting experiments on the manufactured part.

Keywords

Deployable antennas, Topology Optimisation, Additive Manufacturing, Antenna rib, PEI, Fused filament fabrication

STRUCTURAL ANALYSIS OF AIRCRAFT FUSELAGE SECTION AND DETERMINATION OF BOUNDARY CONDITIONS AND FATIQUE SPECTRUM LOADING OF ITS CURVED STIFFENED PANELS

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ABSTRACT

The primary objective of this thesis is the determination of the optimum experimental configurations for the experimental investigation of curved stiffened panels behavior. A test rig of this type should be capable of simulating the structural response of aircraft fuselage sections under static and fatigue loading. A virtual representation of a fuselage barrel is constructed, and its validity checked for simple load cases after comparing stress results with those from analytical and semi-empirical formulations. The finite element model of the fuselage is characterized by geometrical dimensions and material content typical for passenger airplanes. The literature research conducted, aims to propose potential experimental assemblies that impose a specific set of boundary and loading conditions unto the panel. The sources reviewed, were focused on setting up test-rigs that accommodated panels (at test article or component level) for buckling testing with the presence of internal pressure. At the same time, after recreating a fuselage in FE format for post processing data comparison with potential panel models, it is attempted to code a fatigue spectrum as a load sequence. The methodology for producing alternating fatigue stress cycles, that share similar attributes with those attained from real in-flight measurements, is presented in all its phases. The method to end up with a random load sequence, which simulates real life flight conditions, is based upon the exceedance diagram of the normalized stresses, the definition of different flight types and the ordering of the load factors in dimensional form. The present paper juxtaposes the fatigue spectrum obtained through the application of the original methodology with that from, a modified, adapted for fuselage damage inspection and repairs, approach put forward by the FAA. Additionally, as a final step, a third possible load sequence is seeked out, unique to this thesis that utilizes vertical acceleration data,

that correlates to normalized bending stress amplitudes, for the definition of a novel flight block, meaning a fatigue spectrum that corresponds to a given number of flights.

Keywords

Stiffened panel, test-rigs, virtual modeling, fatigue spectrum

DEVELOPMENT OF MODIFIED TENSYLON FABRICS FOR ANTI-BALLISTIC PROTECTION

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ABSTRACT

The purpose of this paper is to improve the anti-ballistic properties of rigid lightweight body armour plates used in military and civil-commercial applications. The rigid panels in these applications are laminated structures of ultra high molecular weight polyethylene-UHMWPE (brand name Tensylon®). To reinforce the panels, surface modification of Tensylon fabrics was performed using particles from nano-reinforced and non-reinforced thermoplastic materials. The developed multilayer structures, comprised of 5 distinct layers, that resulted from the above process, are the following: SKIN, HDPE NEAT, HDPE DOPED, HDPE DOPED 3D. SKIN is defined as the product made of the basic material, Tensylon, and is meant for baseline reference and comparison against the subsequent, surface-modified products. HDPE NEAT is the HDPE powder-reinforced product, made through the process of powder scattering. HDPE DOPED is the product with HDPE of 10% wt. GNPs powder reinforcement, also made through the process of powder scattering. Finally, HDPE DOPED 3D is the product made using a 3D printed reinforcement pattern of HDPE with 10% wt. GNPs. Each different product underwent a high velocity impact test. During the experiments, the velocity of the sphere/bullet before and immediately after the impact, was recorded. The energy absorbed during the impact was then calculated (using these velocity values) as well as the percentage of the energy absorbed by the product over the energy of the sphere/bullet right before the impact. The conclusion according to the results is: The presence of HDPE in Tensylon, as reinforcement, introduces additional absorption mechanisms in the material. In addition, the attempt to integrate nanomaterials into HDPE DOPED material did not yield the desired results. One possible explanation is that, due to their size (25 micrometers), they created agglomeration inside the material. Consequently, they did not contribute positively to the material's structure and degraded the properties of HDPE. Finally, the powder scattering method is superior to the 3D printing method in terms of reinforcing the basic material. This is due to the larger amount of material that was added during the 3D printing method which did not allow the nanomaterials to be embedded properly.

Keywords

Anti-ballistic vests, Tensylon, HDPE, GNPs, high-velocity ballistic impact test

STRUCTURAL DESIGN OF MAST AND RIGGING MADE OF FRP COMPOSITES FOR A RACING SAILING BOAT

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ABSTRACT

Mast and rigs of a sailboat are the structural components responsible for transferring sail loads to the ship's hull, thus, converting wind energy into kinetic energy. Masts are long and slender structures which should have sufficient stiffness and strength properties to effectively carry sail loads without buckling or exhibiting material failure. Composite materials are chosen when designing a mast tube not only due to their high strength- and stiffness-to-weight ratios but also due to the customizable properties of the final product their anisotropic nature offers. In this thesis, a composite mast of the 14m long sailboat 'Oneiro' is structurally analyzed and redesigned accordingly. An Analytical Method, based on Nordic Boat Standard, and a Finite Element (FE) Method, based on a Germanischer Lloyd Guideline, are selected and compared for the dimensioning and structural validation of mast, spreaders and shrouds. Buckling and material failure of the mast tube is assessed through these analyses. Moreover, an additional FEA, considering pretension of shrouds is performed, in purpose of evaluating the effect of this 'real-life' procedure on the elastic behavior and structural integrity of the mast and its components. However, in these FEA mast tube is generated from beam elements, thus, the various openings for different attachments along its length are not considered. For this reason, a FE Model of the mast with shell elements, including each real hole and opening, is structurally analyzed. Material failure is exhibited on critical mast segments close to openings, thus, patches with extra fabric plies are placed accordingly to offer sufficient support and eradicate failure.

Keywords

Mast, Structural Design with Composites, Pretension of Shrouds, Shell Model, FEA

BOUNDARY ELEMENTS SOFTWARE PACKAGES FOR SOLVING CATHODID PROTECTION PROBLEMS

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ABSTRACT

Corrosion is a natural phenomenon that occurs in metals when those are located in corrosive environments. Metals used for mechanical purposes are meant to be working in corrosive environments as offshore structures, subsoil provision even the atmospheric air is corrosive for metals. Therefore, a method to protect metals from corroding is necessary. Cathodic protection is a widely known method that protect metals from corroding. Cathodic protection is divided in two major protection categories. The first one is the method of sacrificial anodes and the second one is the method of impressed current density. Both those methods tend to protect the metal by converting the metal into a cathode. Designing a cathodic protection system requires an accurate determination of the electric potential and the current density, at the electrodes surfaces. Hence a proper modeling for the problem is extremely important. The most common methods to model a cathodic protection problem is the Boundary Element Method (BEM) and the Finite Element Method (FEM). The boundary element method is an ideal method to model and solve cathodic protection problems owning the fact that meshes only the boundary of the electrodes, in comparison to the finite element method that models the whole domain of the problem. In conclusion the boundary element method manages a more accurate analysis of the problem, with precise results and less computation time. For this project COMSOL Multiphysics and FEAC'S PITHIA was used, to simulate cathodic protection problems with BEM. The results from those two programs have been compared with the analytical results, which have been solved in a MATLAB developed programs.

Keywords

Cathodic Protection, Corrosion, Boundary Element Method, Sacrificial Anodes, Impressed Current Cathodic Protection

NUMERICAL INVESTIGATION OF THE INTERLAMINAR FRACTURE TOUGHNESS OF CFRPs MODIFIED WITH NANOPARTICLES

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ABSTRACT

The Objective of the present thesis is the simulation of the delamination between two adjacent nano doped composite plies. Firstly, a brief introduction in composite materials is made. Information about the reason composites are used, some of their applications, their benefits and a historical background is provided. The types of composite materials are also categorized. The meaning of modeling, the reasons which make it an important tool and the connection between fracture mechanics and composite materials are given. Also, the fundamental energy fracture criteria and the basic fracture principals are presented. The concepts of the Griffith energy fracture criteria, the fracture resistance Gc or interlaminar fracture toughness, the energy released during fracture, the K factor of traction intensity and the fracture modes I, II, III are explained for isotropic and homogeneous materials. Also, an interpretation of the delamination and the methodology of designing experiments that follow the standards of ASTM and AITM is given. Afterwards, the concept of cohesive elements such as the experiments that they are capable of modeling, the laws that they follow and the connection between the strains and stresses that they experience are described. The explanation of the cohesive layer, the cohesive zone, the cohesive zone model and the connection between the elastic properties of the material and the numerical parameters related to the model are given. The advantages of the use of the cohesive elements to model an experiment are also mentioned. To continue, the definition of nanomaterials and nanoparticles is given and the categories of composite materials reinforced with nanoparticles are cited. A reference was also made about graphene. A review of the Graphene Nanoplatelets and Carbon Nanotubes is provided and the methods of dispersing nanoparticles in the polymer matrix are numbered. In the fifth chapter of the present study, a brief review is made based on scientific papers which concentrate their interest in finding the effect of the nanoparticles made by graphene in the delamination of composite materials, in the fracture mechanisms which are introduced by their dispersion in the matrix and in how to model this fracture mechanisms to obtain numerical results which accord with those of the experiment. Also, the parameters and mechanisms capable of affecting the modeling of delamination of composite materials are located and a flow chart is designed, to delineate the procedure of modeling. In the present thesis, the results of the simulation of the delamination experiments of CFRP specimens with and without enclosed nanoparticles, for Mode I and Mode II loading types are presented and compared with the real experimental results. Finally, some conclusions 3 about the simulation results and procedure are given with expectations for future research.

Keyword

numerical investigation, delamination, composite, Graphene nanoparticles, cohesive elements

FINITE ELEMENT SIMULATION OF 3D PRINTED LATTICE CORE SANDWICH STRUCTURES UNDER DYNAMIC LOADS

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ABSTRACT

The constantly evolving Additive Manufacturing (AM) technologies offer the possibility of manufacturing parts tailored to the user's needs, in a short period of time, minimizing resource losses, while keeping production costs relatively low. At the same time, they offer freedom in design, allowing the creation of complex geometries, enabling the design of lightweight parts. Lattice structures are complex structures that can be easily produced with the use of AM technologies and are increasingly accepted. Low weight, high strength, good energy absorption, vibration reduction, combined with material savings, are some features of these structures that make them attractive for use in the fields of aeronautics, aerospace, automotive and medicine. The purpose of this work is the construction of sandwich cellular structures using a 3D printer, their static characterization in transverse bending and compression, their dynamic characterization and finally the development of a finite element computer prototype to simulate their behavior, under the respective loads. Specimens with three different types of TPMS unit cells (Schwarz Diamond, Schwarz Primitive and Gyroid) and three porosity values (70%, 75% and 80%) were designed and fabricated via SLA 3D Printing method. The next step was to perform experimental modal analysis, three-point bending test and compression test for all the fabricated specimens, and to model the respective procedures using a Finite Element Software. The results of the numerical analysis were compared with those of the experimental tests, while investigating the effect of the unit cell type and the porosity value on the behavior of the specimens. The constructed model approximates quite well the linear response area of all specimens, for all loads, while it was observed that the increase in the porosity value leads, as expected, to a degradation of the mechanical properties for all unit cells.

Keywords

Lattice structures, Finite Element Analysis, Modal Analysis, Three-point bending, Compression

SIMULATION AND ANALYSIS OF THE THERMOMECHANICAL RESPONSE OF AN SMA TORSIONAL ACTUATOR IN THE TIME DOMAIN

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ABSTRACT

Nowadays, the increasing need for the development of systems and structures complying to strict requirements such as mass and noise reduction promote the use of active materials. Active materials offer some kind of functionality, such as shape modification and recovery of the initial configuration upon thermal or mechanical stimuli. The present dissertation examines the thermomechanical response in the time domain of a rotary actuator in particular a torsional one, made of shape memory alloys (SMAs) in order to bring out the aptness of SMA's in this type of applications and assess its potential. First of all, the special behavior of SMA is described, both in microscopic and macroscopic scale. Afterwards, using ABAQUS finite element software, the torsional actuator was modeled and subjected to a single thermomechanical load case to examine the effect of various heating methods, different thermal boundary conditions and different geometry on its response. Induction heating was selected out of the three different heating loads which are presented in this thesis, along with adiabatic thermal boundary conditions in order to design a full thermomechanical actuation circle so that the shape memory effect is activated. Through this circle the actuator achieves deployment and retraction for a range of 0° to 7,6° in 15 and 20 seconds respectively. Those types of actuators can be used for applications with medium or slow response requirements. Finally, through the comparison of the model's analytic results we conclude in defining not only the way but also to what extend different parameters affect the response of the SMA rotary actuator.

Keywords

Shape memory alloys, Shape Memory Effect, thermomechanical behavior analysis in time domain, torque tube actuator, rotary actuator, Induction heating, actuation circle

DESIGN, STRUCTURAL ANALYSIS AND MATERIALS MECHANICAL CHARACTERIZATION OF A SMALL, REMOTE CONTROLLED HYBRID AIRSHIP

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ABSTRACT

The purpose of the present diploma thesis entitled 'Design, structural analysis, and materials mechanical characterization of a small remote controlled hybrid airship' is the design of a semi-rigid airship which will be provided with buoyancy from a low-density gas and aerodynamic lift using a wing when demanded. The design includes structural analysis of the semi-rigid envelope and the aerodynamic surfaces, selection of suitable materials via experimental methods and calculations for several different flight circumstances. The main design criteria will be safety and weight. The airship is to be used for multiple roles; therefore, the design process will be centered around the ability of payload delivery. By the end of the design process the number of defined parts will be enough for the construction of an operational prototype.

Keywords

Airship, Hybrid Airship, Semi-rigid Structure, Wing

LASER ASSISTED JOINING OF GLASS TO METAL AND GLASS TO POLYMER COMPOSITES

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ABSTRACT

In the present thesis, lap joints of dissimilar materials such as glass, metals and polymer matrix were investigated and developed using emerging technologies based on pulsed laser source systems. The study consists of a wide literature review on the joining of materials, the experimental set up investigation, the experiment procedure and the mechanical characterization of the joints. Firstly, the broad usage of the term "joining" two materials was defined, while in the second chapter a comparison between the two basic categories of joints (mechanical and welded) is taking place. Moreover, to have a better understanding of the available thermal bonding and adhesive bonding methods used by the industries to join polymer plastics to each other, a review of them was carried out, while all the available information obtained from literature research in several scientific articles, publications, websites and doctoral dissertation theses, related to the laser welding of different types of materials such as plastics (thermoplastics and thermosets), metals and glasses are presented. One method of interest is to join dissimilar materials using laser source. Laser joining has many advantages such as short processing time, small heat affected zone and effective usage on different types of materials. Two material combinations were used in the Laser welding experimental procedure, Extra Clear Glass to Aluminium and Extra Clear Glass to 3D printed PLA samples. Polylactic Acid (PLA) being one of the most common and promising biopolymers used with increasing consumption day by day, it is emerging as a substitute for petroleum-based polymers which are used as a matrix in the composite materials. The samples were joint via Laser Transmission Welding (LTW) and Laser Direct Welding (LDW) principals, furthermore laser related parameters were clearly determined in order to get a strong adhesion. Finally, the mechanical shear strength obtained by laser welding methodology can outreach by surpassingly high percentage, 400 – 500 %, the ultimate adhesive bond strength.

Keywords

Laser Welding, Glass to Metal, Joints, Glass to Polymer, Pulsed Laser.

FATIQUE BEHAVIOUR OF OPEN-HOLE COMPOSITES CONTAINING BIS-MALEIMIDE POLYMER AS SELF-HEALING AGENT

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ABSTRACT

In the current diploma thesis, Bis-maleimide (BMI) self-healing (SH) resin based on Diels-Alder (DA) reaction mechanism was integrated into high performance carbon fiber reinforced plastics (CFRPs) by using two variants of electrospinning process technique: (i) the solution electrospinning (SEP) and (ii) the melt electro-writing process (MEP). After modification, all CFRPs were exposed to quasi-static tensile tests, fatigue tests under tensile-tensile loading conditions, while their self-healing capability was further assessed. Based on these, reference and BMI modified CFRPs containing (open-hole, OH) or no hole (unnotched) having $[45°/-45°/0°/90°]_{2S}$ stacking sequence were fabricated for the needs of the current study. In the case of modified CFRPs, 1 wt% of graphene nano-platelets (GNPs) were also incorporated into SHA resin to further modify the CFRPs. The SHA was incorporated locally on the center of each CFRP and surrounding the hole (in the case of OH CFRPs). Unnotched CFRPs were tested only under quasi-static tensile tests, while OH ones were tested under both quasi-static and fatigue conditions. According to quasi static experimental results, it was shown that the incorporation of the BMI SHA led to decrease in strength and stiffness for the unnotched specimens, while for the OH specimens it led to decrease in stiffness and slightly increase in strength. The BMI-GNP modified by SEP specimens (both unnotched and OH) showed the best tensile properties. Fatigue tests showed similar behavior for Diploma Thesis Marianna-Georgia Chantzi Department of Mechanical Engineering and Aeronautics –Division of Applied Mechanics, Technology of Materials and Biomechanics 2 all tested material types: as the cycles progressed the apparent modulus of the specimens decreased and the hysteresis loops moved towards higher strains. The incorporation of the BMI SHA led to increase in fatigue life of most of the modified specimens even by 50%. The application of the healing cycles showed partial restoration of the damage as observed in c-scan plots. The modified CFRPs (BMI and BMI-GNP) by MEP, exhibited the best behavior under fatigue tension-tension loading. Finite element models (FEM) for the simulation of quasi-static tensile tests of modified OH CFRPs were developed utilizing cohesive contact interactions to account for interlaminar delaminations. All analytical models withstood a higher load compared to the experimental results but were capable of simulating the damage initiation and evolution that was observed in the experiments. The models were deemed satisfactory and helped draw conclusions about the damage evolution in OH modified specimens under tensile loads. In the end of the thesis, suggestions are made for further development of the experimental procedure and the numerical simulations.

Keywords

Composites, Self-healing, Open-hole, Electrospinning, Cohesive Zone Model

COMPARISON BETWEEN THE RESULTS OF EXPERIMENTAL STUDY ON (STEEL-CONCRETE) BOND AND OF MODEL CODE 2010 REGULATIONS

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ABSTRACT

Premature ageing phenomena of reinforced concrete structures have declared corrosion of reinforcing steel as the main cause of degradation of the structure's performance and durability. Particularly in Greece, large number of structures is found in coastal regions where the high chloride concentration is enhancing the corrosion to happen and thus deteriorating the proper functioning of the reinforced concrete. From the multilevel negative effects of corrosion, the bond mechanism between steel and concrete is primarily affected, as due to the development of ferrous oxides the conditions at the interface between the two materials are altered, thus limiting the ability to transfer forces.

In the regard, the present dissertation focuses on the degradation of the bond mechanism due to corrosion by studying it in two axes. Specifically, in the first axis of the study, the degraded bond due to corrosion was simulated through the modeling of pull-out tests carried out in the Laboratory of Technology and Strength of Materials. The main parameters that were examined were: the degree of corrosion of the reinforcing steel and the level of confinement through stirrups, distinguishing the cases: a) absence of confinement (without stirrups) and b) moderate confinement (stirrups Ø8/120 mm). From the development of the analytical model in the Abaqus finite element software it emerged that the model is in satisfactory agreement with the exported experimental bond strength values under both reference and corrosion conditions. The prediction of the relative slip of steel-concrete is satisfactory as well, in the case of stirrup's presence, while in the absence of stirrup and in association with corrosion conditions the prediction lags.

An important observation is that the level of confinement, through different density of stirrups, noticeably differentiates the rate of decline of the bond strength. Studying the corresponding recommendations of fib Model Code 2010, where the bond strength's drop due to corrosion is predicted, taking into account the degree of corrosion of steel (in terms

of corrosion penetration or crack width on the concrete surface) and the absence or presence of stirrups regardless of their density, the second axis of the work was established. In the axis, results of bond loss due to corrosion were collected from various studies of the recent international literature and after being divided into groups based on the level of confinement (distance between the stirrups) a statistical analysis was performed to derive laws predicting the bond loss. The present study showed that increasing the degree of corrosion in steel causes an exponential decrease in the bond strength, the rate of which depends significantly on the density of the stirrups. So, in this manner, it is proposed to categorize the different levels of confinement of RC components, in order to represent different cases of stirrup density, recognizing the following levels: No confinement (absence of stirrups), and in the presence of stirrups Light, Medium and Strong confinement. Based on the above, from the nonlinear regression analysis of the experimental data, a one-parameter exponential function was adopted to predict the bond loss (depending on either the depth of corrosion penetration in the steel or the width of the surface cracks). The results of the analysis showed that the value of the parameter of the exponential predictive models depends on the density of the stirrups and decreases with increasing level of confinement.

Keywords

Reinforced Concrete, Bond Strength, Corrosion, Average penetration depth, Average surface crack width, finite element modeling of bond based on Model Code regulations

DIVISION OF DESIGN AND MANUFACTURING (FEBRUARY 2022)

DESIGN OF 3D PRINTED METAL PARTS USING SELECTIVE LASER MELTING TECHNOLOGY (SLM)

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ABSTRACT

Additive Manufacturing is an important part of the Production and Manufacturing sector in our days. Additive Manufacturing technologies are predominantly used in the global market; the majority of construction companies have integrated the Additive technology in the production line. The main advantages that this technology offers are; flexibility, customization, low cost and high speed compared to conventional manufacturing methods. As about the early years of Additive Manufacturing, it was initially more common in printing plastic models and adopted mostly by amateur craftsmen or hobbyists. In recent years, however, it has certainly a major role in the Automotive and Aerospace industries, because it cannot only be applied into plastic components or generally low-strength components, but it also enables the printing of metallic machine elements with equivalent or even better mechanical properties than components constructed by conventional technologies.

The basic method used for 3D printing of metallic machine elements is the Selective Laser Melting. This method uses materials in the form of powder and the process followed is to melt and then solidify the material using a high power Laser. The method of Selective Laser Melting seems to meet the requirements and is considered to be worthful for a construction industry, as it brings an excellent balance between quality, quantity and cost. The main reason that this method is expected to induce an industrial revolution in the future, is that it makes able to create customized components in a very short period of time, which can repair the equivalent ones in specific cases. Furthermore, because of the original process of the additive technology, the weight of the components produced can be much lighter than

the conventional ones that are used so far, let alone the fact that the weight is a very important factor in the Aerospace and Aerospace industry. The present thesis was initially oriented towards the understanding of the theoretical background and the basic principles of the method of Additive Manufacturing. It also gave emphasis and showed special interest into the field of Topology Optimization, which is offered by the method, as well as to the advantages that such an optimization and flexibility can have in the final component.

In addition, the topology optimization of a product requires flexibility in the way it is made and additive technologies are the most appropriate to implement such improvements. As about this work, it is focused on the creation of a numerical model; a beam constructed by conventional technology and another one with 3D printing. Both of them had common boundary conditions, fixed to one edge and a range of forces constrained to the free edge.

The modeling and the final results of the analysis were done with the aid of Ansys Software. At the first stage of this study the unknown values were the analyzes of stresses, deformations and equivalent elastic deformations along the beam for both cases as well as a suggesting topological optimization in the beam of three-dimensional printing in terms of lattice density and mass reduction. Afterwards, the numerical results from the 3D printed beam were compared with the experimental results of scientific articles as well as with the numerical results of conventional beam. Special importance was also given in the appropriate selection of finite elements for both beams, as the selection of these elements affects (meshing) the quality of the analysis results and finally the result of the topology optimization of the 3d printed beam was commented. At the second stage of this study, there was a thermal analysis of the 3d printed beam dye to calculate the thermal stresses, deformation and temperature distribution at macroscale. Also, there was a simulation of moving laser source and defining the rest of the boundary conditions of the problem. At last, another topology optimization in order to reduce mass made, taking into account the thermo mechanical stresses that develop in the beam. Finally, in the present study, an attempt was made in order to develop a Modified failure criterion at its early stage, based on the Deformation Theory (Von mises), which was also individualized to the method of Selective Laser Melting. Last but not least, it is referred that the conceptual idea was a criterion that corresponds to reality and be close to realistic results as possible as about the failure of the component, taking into account the actual data of the process which are in addition to the main stresses that developed in the component, the thermal and the remaining stresses too.

Keywords

Selective Laser Melting, Thermomechanical analysis, Topology optimization, Modified failure criterion, Moving boundary condition

A STATE OF THE ART ON MACHINE LEARNING ALTGORITHMS TOWARDS A FRAMEWORK FOR THE DESIGN AND DEVELOPMENT OF A FLEXIBLE MANUFACTURING CELL

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ABSTRACT

Manufacturing Systems and Automation has faced a rapid evolution/digital transformation during the fourth industrial revolution or Industry 4.0. This thesis embarks on an investigation of the trends and advancements in the field of manufacturing systems and the underlying algorithms over the last decade, with the focal point being the Machine Learning (ML) and Artificial Intelligence (AI) frameworks. Furthermore, the shift of manufacturing systems towards automation gave birth to a humongous volume of data. Thus, techniques to utilize and organize all this data for the benefit of contemporary industries, using smart manufacturing systems, are proposed in this thesis. Furthermore, a core element of this diploma thesis is Machine Vision (MV). Initially, the definition of MV, is provided the fundamental methods developers should follow, in order to build a proper MV system are analyzed. Additionally, examples of MV frameworks in modern industry are displayed and analyzed. Moreover, with ML and AI being in the core of this research, following their definitions, applications in manufacturing, frameworks, architectures and systems based on ML in industrial case studies are then presented. Moreover, this research looks into Flexible Manufacturing Cells (FMCs) and their employment in modern manufacturing. Following the definition of FMCs, their Advantages and Disadvantages are presented together with the FMCs' component analysis. Lastly, as in the modern industry application of FMCs the use of Computer-Aided-Design (CAD) is of critical importance, hence current advantages of CAD files and ways to utilize their data, to contribute to the automation of the FMCs effectively and efficiently, are researched and proposed within this diploma thesis. In conclusion, this thesis essentially probes into the Process planning of FMCs and a framework that promotes strategies and technologies to achieve the desired framework, as well as the conclusions, and future work, based on this thesis implementations, are handed out and further analyzed.

Keywords

Manufacturing Systems, Artificial Intelligence Machine Learning, Machine Vision, Flexible-Manufacturing-Cell (FMC)

DIGITAL TWIN FOR FAST AND FLEXIBLE PROGRAMMING AND CONTROL OF COOPERATING ROBOTS IN RECONFIGURABLE PRODUCTION SYSTEMS

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ABSTRACT

The shift from mass production to product personalization is the main enabler behind Industry4.0 and drives the development of modern production systems. This in turn creates the need to deploy flexible and reconfigurable assembly systems. This Thesis investigates the use of Digital Twinning in such production systems for enabling system flexibility and reconfiguration through various functionalities. The suggested Digital Twin (DT) infrastructure involves two main components: a) Virtual representation of the shopfloor, combining multiple sensor data and CAD models. The digital shopfloor is rendered in the 3D environment exploiting the capabilities provided by Robot Operating System (ROS) framework, and b) Real-time multi-robot behavior control (using various functionalities). The communication layer among the physical and the virtual agents in the level of the Digital Twin is realized on top of the ROS framework. The integration of the DT in an overall production system with various components (like planning systems) is realised through the Asset Administration Shell (AAS) and a specific resigned ROS- AAS connector responsible for translating data between the two formats. Finally, an orchestration system (Workflow Manager) that is responsible for dispatching planned tasks to the assigned resources has been implemented. The developed infrastructure is applied to a use case study inspired by the consumer electronics industry focusing on the assembly of two different products, a trimmer head, and a monitor cover. Nevertheless, the proposed solution has been designed to be easily applicable to multiple similar cases.

Keywords

multi-robot control, digital twin, reconfiguration, asset administration shell, flexibility

APPLICATION OF ARTIFICIAL NEURAL NETWORK FOR OPTIMAL MOTION AND TASK IMPLEMENTATION BY AGVs IN SPACES WITH VARYING CONFIGURATIONS

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ABSTRACT

This Thesis deals with the issue of finding the optimal path of Automated Guided Vehicles in spaces with varying configurations, making use of Artificial Intelligence and more specifically, Artificial Neural Networks. The solution to the problem is approached with two types of neural networks, the conventional fully connected Artificial Neural Networks (ANNs) and the Convolutional Neural Networks (CNNs).

The aim of the ANN is to find the best possible path for the AGV between the warehouse and five workstations, in environments with variable obstacle configurations. The warehouse is the starting and ending point of the route, while the five stations are the intermediate points, that the vehicle must visit in a predetermined order. The warehouse and the stations have the same fixed locations in every sample. The ANN samples consist of the environment and the optimal path of the AGV for this corresponding environment, calculated by the path finding algorithm A*. The ANN is trained with two types of input samples, correlated and non-correlated.

The aim of the CNN is to solve the general theoretical problem of finding the optimal path in an unknown environment, between a random starting and a random ending point. The general nature of the problem that the CNN aims to solve, makes it possible to apply it to a variety of path-finding problems, including AGVs in industrial environments.

Keywords

Artificial Intelligence, Path Planning, AGVs, Artificial Neural Networks, Convolutional Neural Networks

WORKSPACE MONITORING FOR HRC ENVIRONMENTS: OPERATOR POSITION TRACKING AND FUTURE TRAJECTORY PREDICTION USING AI

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ABSTRACT

Industrial environments are characterized as complex, unstructured, and crowded. The local perception of the robot is limited, having a big impact on its performance (e.g. operation speed, path replanning) and safety (e.g. unexpected elements crossing through the robot's path or found after a turning). In the implementation of hybrid production systems, workspace sharing introduces mandatory and challenging safety aspects. Any place in which autonomous robots work with humans requires constant surveillance, to guarantee that no operator nearby is put in danger by the robot. It is important that monitoring applications ensure that the position of the robot with respect to humans is always known and with high accuracy and a fast update rate. What is more, for more human safety-centered and collision preventive robot motion strategy, the forecasting of the future human movement could be utilized by and integrated with the system's motion planner increasing the safety potential of the overall system. In the present thesis, the integration of a workspace monitoring system is described that guarantees the safety of the operators and detects their position within a human-robot workspace, using a sensor network that consists of safety-certified devices for machine safety and depth sensors. Finally, a prediction model is implemented based on neural networks, which can predict the future trajectory of the operator, exploiting data received from the sensor network.

Keywords

Artificial Intelligence, Robotics, Workspace monitoring, Automation, Engineering

IDENTIFICATION OF DYNAMIC PROPERTIES OF BEARINGS USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Nowadays it is a fact that artificial intelligence and its applications radically change our lives and in particular the field of action of a mechanical engineer. The use of intelligent systems, such as artificial neural networks (ANN), in issues of engineering science is increasing, as they have several advantages over the classical methods used. In this work, an attempt is made to determine the coefficients of stiffness and damping of sliding bearings using artificial neural networks (ANN).

The bearings are components of machines with wide application in rotating machines, such as centrifugal pumps, engines of cars, aircraft, propulsion systems of ships, etc. Thanks to them, the static and dynamic balance of rotating machine parts is ensured, as well as the avoidance of development. Frictional forces between relatively moving surfaces. For this reason, the performance and reliability of many mechanical systems depend on them. Determining the dynamic characteristics of bearings is particularly important, as they affect the whirling effect, critical speeds and oscillation amplitude of rotating systems supported by bearings.

First, the necessary theoretical background on bearings as engine components is presented and basic concepts of lubrication theory and the theory of dynamic analysis of rotating systems are clarified.

In the next part, the theory of artificial neural networks (ANN) is introduced and the networks used for the purposes of the work are configured through the MATLAB software. In addition, the analysis of a rotating shaft - disk system, through the Mechanical APDL platform of the ANSYS software, is presented.

Finally, the results of the analysis are presented in the form of CAMPBELL diagrams using and comparing data from the literature and the ANN and conclusions are drawn.

Keywords

Bearings, Dynamic coefficients, Artificial Neural Networks.

USE OF GENETIC ALGORITHMS FOR OPTIMIZING ASSEMBLY SEQUENCES

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ABSTRACT

The present work introduces a systematic way to optimize the assembly sequences of a new product during design for manufacturing and production. Initially, the concepts of design are introduced and explained and its phases, tasks and processes that take part in the development of a new product are examined. Reference is made to the processes associated with assembly and production during design and the relevant methods are discussed that solve the problem that requires satisfaction of constraints. References are also included for assembly optimization methods with specific consideration of genetic algorithms. The latter are used for generating optimized feasible assembly sequences. The implementation of the proposed method has been done in Python and is exemplified through an assembly application of the parts of a small manual press. The present work sets a method and a useful tool that solves an important problem of the design process when developing new products.

Keywords

Design For Assembly, Assembly Sequences, Optimization, Genetic Algorithms, Python

ROBUST DETECTION OF INCIPIENT FAULTS IN ROTATING MACHINERY UNDER VARYING OPERATING SPEED USING VIBRATION MEASUREMENTS AND ADVANCED STATISTICAL TIME SERIES METHODS

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ABSTRACT

This study explores the potential for incipient fault detection in rotating machinery based on vibration signals and conventional statistical time series methods. The considered faults cause no obvious effects on the time domain signals or their characteristics (e.g., variance), thus leading to a highly challenging problem. In order to address it, vibration measurements are acquired via two sensors in an experimental rotating machinery, consisting of two electric motors coupled by a claw clutch, operating at 21 different speeds. Then, the optimal positions of the sensors are investigated based on their sensitivity to faults through Welch-based Power Spectral Density (PSD) based criteria, as well as through coherence and transmittance functions. The signals acquired from the most sensitive to fault sensor are non-parametrically analyzed via the Welch-based method and are also modeled through Autoregressive (AR) models in order to identify the partial dynamics of the rotating system. Three incipient fault scenarios are investigated, with the first and second corresponding to a reduction in the tightening torque of a single motor's mounting bolt (two reduction percentages), while the third corresponds to artificially induced slight wear on the claw clutch's spider (two propagation percentages), which is 3D-printed. The detection is performed through the non-parametric PSD-based method and also via the AR models parameter-based method. The results demonstrate perfect detection performance for both methods at constant speed condition, with a 100% True Positive Rate at 0% False Positive Rate, based on 126 healthy-experiments and 756 faulty-experiments. The weakness of the conventional statistical time series methods to detect incipient faults under varying operating speeds, highlights the need for advanced methods addressing this problem.

Keywords

Rotating Machinery, statistical time series methods, vibration signals, dynamic identification, incipient Fault Detection

CONCEPTUAL DEVELOPMENT OF A KNEE SIMULATING DEVICE FOR FRICTION AND WEAR TESTING OF BIOMATERIALS

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ABSTRACT

Over the past decades, the field of knee joint simulating devices has been constantly evolving. Different kinds of experimental simulators offered valuable insight over kinematic and loading behavior of a natural or artificial knee joint. However, as human life expectancy constantly increases, people tend to experience more and more fatigue around their knee joint, resulting in intense wear and pain, thus experiments over the new prosthetic technologies introduced have to accommodate accelerated and more demanding testing regimes of variant daily and sport activities.

The main objective of this study was to develop a novel dynamic knee simulator that not only abide to but surpassed the requirements of the ISO 14243 Standard [1, 2], including the operating frequency, specimen mounting, positioning & alignment, range of motion and in-vitro conditions such as the incorporation of lubrication, temperature, and pH control systems.

The first development step included the conceptual design of the simulator and its optimization using CATIA (Dassault Systèmes, Vélizy-Villacoublay, France) designing software, where factors such as design for assembly (DFA), design for manufacturing (DFM), ease of maintenance, safety measures and modularity determined the final result. Some of the key characteristics of the apparatus were the 6 degrees of freedom permitted between the two articulating bones with five controlled axes, the option to mount and investigate the performance of specimens regardless of their size, as well as a custom fluid test medium enclosing capsule that did not interfere with the outgoing procedure, even at the maximum flexion angle of 120 degrees.

The next step was to investigate the structural integrity of the conceptual design introduced, by imposing severe static loading conditions to replicate complex daily activities by using the ANSYS Static structural software. Finally, through a modal analysis, vibration characteristics were inspected to ensure that the machine operated at a frequency different from its natural ones, so resonance could be avoided. Throughout the simulations, a mesh independence study in conjunction with non-linearities were included, to obtain more realistic and accurate results. According to the findings of this study, the introduced conceptual design of the knee simulating device was functional and reliable.

Keywords

Knee Simulator, Conceptual Design, Static Structural Analysis, Modal Analysis, Biomechanics

DEVELOPMENT OF A CONTROLLER FOR FORCE MULTIPLICATION IN A HUMAN-POWERED ROBOTIC ARM FOR MACHINING OF NON-PREDETERMINED TRAJECTORY

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ABSTRACT

Due to the advancements of technology robots are utilized in more and more fields. Their role except of totally autonomous is greatly orientated in collaboration with humans. The human – robot collaboration requires the development of controllers for the processes, while they provide enough safety to the user. This collaboration is usually intended for transportation and placement of objects or implementation of machining processes. In the field of material processing the robotic arm carries the tool that the operator moves, most of the time following a predetermined trajectory. Its purpose is the force degradation or multiplication of what the user applies through the load applied by the robotic arm. In these applications force or position controllers are used, depending on the nature of the process they have to carry out and the physical properties of the material to be processed. In this paper such a controller for a human – robot collaboration system is developed. The robotic arm has the role of an intelligent tool carrier, while it applies the suitable force for the amplification of the initial load applied by the user. The user guides the robotic arm from the grip of the specifically designed handle that is mounted at the robot's end-effector, without the need to follow any predetermined trajectory. The controller is designed for materials' machining processing, aiming at applications in the field of robot sculpting. At the end of the study the system is tested on a metallic piece, processing two of its vertical surfaces, in which its effectiveness and the satisfaction of the standards that it's called to meet are checked.

Keywords

Force controller, Robot handle, Force amplification, Human–Robot co-manipulation, Non-predetermined trajectory.

DESIGN OF AN AUTOMATIC TOOL CHANGER FOR COLLABORATIVE ROBOTS

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ABSTRACT

Robotic units are extensively employed in the manufacturing sector because they can execute tasks with accuracy and repeatability. The implementation of robots has proven to be a great investment since they can replace human workers in repetitive processes and in hazardous environments. The rise of industrial robots was followed by the rise of collaborative robots that are made to work safely near humans without protective barriers. Collaborative robots can be used for the automation of a variety of tasks working with and helping human workers. However, the need of increased automation to maximize productivity leads to the assignment of a variety of tasks to individual collaborative robots. The ability of a robot to carry out different tasks is proportional to the tools that it can use, so it is important for the robot to be equipped with a system that will allow efficient change of tooling. This diploma project goes through the design and development of an automatic tool change system which consists of a tool pick device and a tool holder.

Keywords

Automatic tool changer, Robot tool changer, Collaborative robot, Tool changer analysis, Tool change device.

TRAINING OF AN ARTIFICIAL NEURAL NETWORK IN LEARNING THE OPERATION OF A MOTION TRANSMISSION SYSTEM - THE CASE OF A BICYCLE

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ABSTRACT

In the present thesis, the development of an Artificial Neural Network (ANN) which is able to predict the desired gear ratio of a motion transmission system of a bicycle is presented. The development of the Artificial Neural Network has been based on data that correlate the cycling conditions with the gear ratio set by the cyclist. The ANN was then trained to learn the operation of the motion transmission system of the bicycle. Due to the fact that this kind of data were not available, they were instead generated by using the kinematic and physical model of the transmission system of a bicycle and by calculating the optimal gear ratio with regard to external conditions and characteristics of the cyclist. Then the data so produced were used to train the ANN. The thesis also contains a study on the optimal architecture of the Artificial Neural Network that ensures low error regarding the estimation of the desired gear ratio.

Keywords

Artificial Neural Network, Artificial Intelligence, Deep Learning, Machine Learning, Motion Transmission

DETECTION OF INCIPIENT FAULTS IN A RAILWAY VEHICLE SUSPENSION UNDER VARYING SPEED AND PAYLOAD VIA ADVANCED MACHINE LEARNING METHODS AND TIME SERIES OF VIBRATION SIGNALS

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ABSTRACT

This study explores the problem of fault detection in railway vehicle suspensions using on-board vibration signals collected under different travelling speeds and payloads, and advanced machine learning type methods. A high-fidelity railway vehicle model of 54 degrees of freedom has been developed in Simpack including rail excitation in all potential directions (vertical, lateral, cross level), as well as rail infrastructure sleepers. Based on this, 1 050 Monte Carlo simulation experiments have been performed with the healthy and faulty vehicle, travelling with typical operating speeds in the range of 70 - 80 Km/h, payload that varies from 0 up to 88 passengers (each of mean mass equal to 75kg), and a different realization for the excitation per rail. The considered scenarios with the faulty vehicle correspond to a single fault per test case through the reduction of the stiffness and damping characteristics of the conical rubber spring in the primary suspension (5%, 10%, 15%, 20%, 25%) and the secondary suspension's air spring (15%, 20%, 25%, 30%, 35%). Fault detection is attempted via four Unsupervised (U) machine learning type methods, three of which using the concept of Multiple Models (MMs) for the representation of the vehicle healthy dynamics under varying Operating Conditions (OCs), while this is achieved through a proper Functional Model based on the fourth method. All methods employ the Transmittance Function (TF) of a pair of vibration signals acquired from accelerometers with properly selected locations on the vehicle as the feature for fault detection, which offers high sensitivity to damage and partial or full cancellation of uncertainties due to unmeasured and/or unknown excitations. A non-parametric U-MM-TF based on the well-known Welch estimator, and two parametric U-MM-TF-ARX and U-MM-PCA-TF-ARX based on AutoRegressive with pseudo-eXogenous (ARX) excitation models and Principal Component Analysis (PCA) are used in the MM framework, while a Vector-dependent Functional Pooled TF-ARX (VFP-TF-ARX) model is used in the Functional Model Based Method (FMBM). The effects of the considered faults on the vibration signals Transmittance Function and the significant overlapping by the effects of the considered OCs indicate on the one hand that these are early stage or incipient faults and on the other that the explored problem is highly challenging. The detection results indicate the overall superiority of the FMBM which achieves the detection of faults over 15% in the primary suspension and over 25% in the air spring with 100% and ~87.8% correct detection, respectively, for false alarm rate of 5%. From the MM-based methods, the best fault detection performance is achieved via the U-MM-PCA-TF-ARX, which yet does not detect any fault in the air spring.

Keywords

Incipient Fault Detection, Varying Operating Conditions, Railway Vehicle Suspension, Vibration based Statistical Time Series, SIMPACK

BROKEN MECHANICAL BEHAVIOR OF THE TEETH IN THE TOOTHED RULES

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ABSTRACT

The purpose of this thesis is to simulate the fracture of a gear that shows cracks in its sloping side. The study is carried out using the method of finite elements and the help of the Lusas project. Initially, an introduction to the theoretical part of gears and the entities that describe them is being made, focusing mainly on the rack-gear pair. Through Lusas, models with a different module, depth and crack position are created, in which a load is applied at five different positions on the tooth's sloping side. Reference is made to fundamental principles of fracture engineering, paying particular attention to the fracture toughness. Moreover, for the models with module =10 is presented the deformed mesh that result from the different effect of the load each time compared to the unformed mesh. Finally, the nodes and their displacements near the ends of the cracks are determined, through which the fracture toughness is calculated. Diagrams are created and through them conclusions are drawn that help to easily understand and study the strength and mechanical behavior of each tooth depending on the crack.

Keywords

rack gear tooth, finite elements, crack, depth of crack, stress intensity factors

VIBRATION BASED DAMAGE DETECTION IN A POPULATION OF COMPOSITE BEAMS VIA MULTIPLE MODEL AND AUTOENCODER APPROACHES

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ABSTRACT

The current diploma thesis utilizes Artificial Intelligence algorithms, specifically Autoencoders and a Multiple Model method to develop a robust damage detection method in a fleet of composite beams used in airplane structures. It is essential in aeronautic structures the detection to happen remotely and while operating to conserve maintenance costs and optimize their flight hours. From the manufacture of the composites which are used in aeronautics variability is introduced in geometric characteristics and especially thickness and makes it harder to develop a robust method to serve the hole fleet of aircrafts. The change in dynamics under the thickness variability of the structure overlaps the one due to damage. The current diploma thesis is invoked to confront this exact challenge. The structure is simulated with Ansys software under stable environmental conditions and is excited using forces modelling wind gusts. The only variability is the beam thickness which is induced during the curing procedure of composite materials. The damage detection doesn't consider input data, it is based upon the vibrating output signals. The beam dynamics are represented by Multiple-Input Single-Output (MISO) Transmittance Functions (TF) stochastic AutoRegressive with eXogenous pseudo-eXcitation (ARX). The ARX parameters are fed to the Neural Network and compose the characteristic vector of Multiple Model. The damage under study is a through thickness crack with distinctive width and three different lengths. The results of the Multiple Model method are optimum even for the small damage scenario while the Autoencoder detects the damages precisely for a high false alarm rate. This may be attributed to the complexity of the neural network.

Keywords

artificial intelligence, multiple models, composite beam, damage detection, structural health monitoring

TRIBOLOGICAL DESIGN OF WATER LUBRICATED BEARINGS-MARINE APPLICATIONS

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ABSTRACT

One of the most important machine elements in rotating machines is the bearing. It has been an integral part of machines since the ancient times (The Egyptians used journal bearings lubricated by animal fat in their chariots) and became even more so after the industrial revolution. The journal bearings are designed in a way that they can surround the machine shaft. The difference between the journal and bearing diameters allow the lubricant to flow through a small clearance. This is very important, since once the shaft is rotating, the hydrodynamic forces created in the lubricant can support the weight of the journal and operating loads in order to greatly reduce friction, temperature rise and most importantly prevent the shaft from coming into direct contact with the bearing which would cause wear and could prove destructive for the machine. It is therefore understandable why there is such interest in the development of journal bearings and their lubricants.

More recently, there has been an increasing need to implement the use of water as a lubricant in ships, as the need to protect the environment has never been higher and the requirements and regulations concerning such lubricants have gotten stricter. R.Pai and D.J Hargreaves et al [2] of Queensland University of technology elaborated on the increasing need for water lubricated bearings and even conducted various experiments so as to better understand the behavior of such bearings. Nevertheless, while great progress has been made in this field there is still a gap in our understanding of the flow phenomena. For example, the ability to accurately predict the equilibrium position of the journal inside the bearing is still quite limited. On the other hand, the equilibrium position of conventional journal bearings has been adequately studied and many different methods have been developed such as the twofold secant method which was used by Zhou et al [3]. In this Thesis an effort will be made to better understand how conventional lubricants and water affect the equilibrium position of the journal and a CFD (computational fluid dynamics) approach will be chosen through the software of FLUENT, in order to extract the results needed for the tribological design of each bearing respectively.

Keywords

Water-lubricated bearings, Marine applications, Computational fluid dynamics, Hydrodynamic lubrication, Green tribology

DIVISION OF ENERGY, AERONAUTICS AND ENVIRONMENT (FEBRUARY 2022)

COMPUTATIONAL ANALYSIS OF FLOW AND THERMAL FIELDS OF A CURVED TYPE VORTEX GENERATOR FOR VARIOUS HEIGHTS AND HOLE DIAMETER IN A RECTANGULAR PIPE

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ABSTRACT

The subject of the present diploma thesis is to investigate the effect of a curved Vortex Generator in the airflow and thermal field of a heated pipe with rectangular cross section. The computational expansion is taken place for different values of height and hole diameter. The aim of following research is to enhance the heat transfer, while achieving low values of pressure drop.

Initially, some theoretical concepts of fluid mechanics were described, such us the different types of flow, the velocity and thermal boundary layer, the vortex, the ways of heat transfer and the operation of Vortex Generators.

As for the computational investigation, the CFD program that used for the simulation analysis is ANSYS-Fluent. Firstly, the geometries were designed and the mesh was constructed. The turbulent model, which used for the solution is k-ε Realizable. The value of constant temperature that applied at the inner pipe-walls is 650 Kelvin while at the inlet is 273 Kelvin.

The variables of the first and second group of simulations were the ratio of Vortex Generator's height to the height of pipe's cross section and the ratio of hole's surface

to Vortex Generator’s surface. From each group, the model with the best results was selected for further analysis applying to its inlet different Reynolds number.

More specifically, in each simulation, the outlet temperature, the average Nusselt number of fluid and Darcy friction factor were calculated. Also, diagrams of these computational sizes were designed for better comparison.

Finally, observations and conclusions that emerged from the investigation were explained and presented suggestions for further research.

Keywords

Ansys-Fluent, Vortex Generator, Heat transfer, Nusselt number, Pressure Drop

COMPUTATIONAL STUDY OF HEAT TRANSFER EFFECTS ON FLAME STABILIZATION IN FULLY PREMIXED METHANE - HYDROGEN FLAMES UNDER LOW INLET REYNOLDS NUMBERS

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ABSTRACT

Natural gas is the cleanest fossil fuel, weakly affected by price fluctuations and with reserves evenly spread over the globe. Among liquid and solid hydrocarbons, it is the fuel with the lowest greenhouse gas emissions. Nevertheless, even reduced, these values have a significant impact on air pollution. To the contrary, alternative fuels, such as hydrogen, are not accompanied by carbon dioxide emissions during combustion, but their use is limited in terms of safety and convenience of transport and storage. The combustion industry faces new challenges in order to increase the efficiency, reliability and flexibility of combustion equipment, in line with the reduction of emitted pollutants, with the attention being drawn on the combustion of mixtures of alternative and fossil fuels.

The present work describes an investigation of the effect of conjugate heat transfer on stabilization of fully premixed hydrogen-methane flames, under low Reynolds numbers. This study explores seven different simulations of a standard geometry, each time changing the heat transfer condition between flame and stabilizer, the inlet velocity, the hydrogen content of the fuel and the equivalence ratio of the fuel-air mixture. The cases of hydrogen fraction in the fuel mixture equal to 0, 0.2 and 0.4 are examined, for equivalence ratios set so that the flame speed takes values of 19.1 cm/s and 10.4 cm/s. The inlet velocity will be 0.5m/s and 1m/s, in each case, while the mixture temperature is set at 300K.

All simulations were carried out using the Laminar model, as well as the Species Transport model for a 35-element mechanism, as implemented in the commercially available software Fluent within the Ansys suite.

Keywords

Flame stabilization, methane-hydrogen mixtures, conjugate heat transfer, premixed flames, laminar flames

LARGE EDDY SIMULATION (LES) OF TURBULENT STRATIFIED METHANE/AIR FLAMES IN A CENTER BODY ANNULAR COFLOW BURNER WITH AND WITHOUT THE INFLUENCE OF SWIRL, USING A FINITE-RATE CHEMISTRY APPROACH AND QUASI GLOBAL CHEMICAL KINETICS

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ABSTRACT

The investigation of the phenomena and the conditions leading to flame anchoring in bluff body geometries are a well-established testbed for studying and extracting information for practical combustor applications. The aim when studying such geometries in laboratory scale experiments, is to devise suitable correlations and conclusions that can be projected to industrial combustors leading to a decrease of the emitted pollutants and an increase in the overall combustion efficiency. Most often the laboratory scale experiments are conducted in low Reynolds number conditions, as well as low pressures, but the conclusions drawn can be very well extrapolated to industrial scale applications, like the aerospace and energy generation industries.

In the present study turbulent stratified methane/air flames stabilized in a center body annular coflow burner, with and without the influence of swirl, using a finite-rate chemistry approach and quasi global chemical kinetics are being investigated. The aim is, on one hand, to consider the effect of fuel stratification in the structure and stability of the anchored flame, utilizing a popular model fuel, methane. Methane is often used as a reference fuel, both due to its neutral combustion behavior and its relevance to mixtures of natural gas. On the other hand, the effect of swirl is assessed in the flame structure and stability of operation. In the above-mentioned studies, the Large Eddy Simulation model is employed, along with a finite rate reaction model and a 14 species semi-global chemical mechanism. The results of the simulations are appraised against experimental data of the literature, in order to test the validity of the computational approach in modelling such flames. Lastly, the

chemiluminescent emissions are estimated using an algebraic model, assuming quasi-steady state of the species concentrations. Those emissions are an important indicator of the flame structure, 4 that is oftentimes measured experimentally or extracted from simulations. All the simulations were done using the commercially available code Ansys Fluent.

Keywords

Large Eddy Simulations, Multi-step chemistry, Semi-global chemical kinetics, Algebraic chemiluminescence model

CREATING AN APP THAT SOLVES PDE USING MODULAR GEOMETRIES

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ABSTRACT

The subject of the present thesis is the natural problem of heat transfer and diffusion under constant temperatures. The basic modes of heat transfer and some of the partial differential equations are explained. Also, the conditions are stated for a problem to be considered well placed.

Moreover, there is an explanation of the term "Computational Fluid Dynamics (CFD)" and its use in the scientific field of Engineering. With the help of finite differences, the equation of heat transfer and diffusion is distinguished, which gives the possibility to be solved by a computer.

The problem in one dimension is defined as the flow of fluid in a pipe of negligible diameter. An analytical solution is implemented using the Python programming language. The code that is generated is dynamic. This means that, it solves not just a specific problem but a set of problems enabling the user to select and change values in many variables. In this context, two or more pipes are paired using the same part of the code. Numerical examples are presented, and the correctness of the code is checked.

In two dimensions, the problem consists of the temperature distribution in a square plate with fluid that flows on its surface. The code that is created is based on the code of one dimension.

Finally, code is developed which solves the two-dimensional problem in various geometries using modular geometries. The choice of geometry is made from a grid of 3x3 plates. For the easier use of the code by the user, a more friendly programming environment is created in the form an application.

Keywords

Convection and diffusion heat equation, Computational Fluid Dynamics, Define elements, Python

COMPUTATIONAL INVESTIGATION OF AERODYNAMIC BEHAVIOR OF THE DRIVAER NOTCHBACK MODEL IN SINGLE-PHASE AND TWO-PHASE FLOW CONDITIONS

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ABSTRACT

Driving safety in various climatic conditions and low CO2 emissions are two of the cardinal standards in the automotive industry. According to the existing literature, these can be achieved through aerodynamic optimization of cars. The ever-increasing use of computational fluid dynamics (CFD) significantly contributes to this endeavour, since it offers the prospect of fast and accurate solutions in the field of automotive aerodynamics. Of course, understanding the complex flow phenomena in these cases is absolutely essential. Therefore,the aim of the present thesis is the study of the basic aerodynamic structures of both the single-phase air flow and the two-phase air-rainwater flow through numerical simulations on the DrivAer model with Notchback rear end configuration. This model is a realistic geometry of a conventional passenger car, designed at the Technical Institute of Munich (TUM) with the contribution of the BMW Group and Audi AG. In order to investigate its aerodynamic behavior at two different flow velocities, it underwent the appropriate geometric simplifications in the Spaceclaim 2021 R1 software and was then discretized with a numerical grid consisted of 9.3 million Polyhexcore cells of the mosaic meshing technology. The simulations were performed in the CFD commercial code Ansys Fluent 2021 R1. The RANS turbulence model Realizable k–ε combined with standard wall functions was employed. Respectively, the two–phase flow was modelled with the Euler-Lagrange approach and specifically with the DPM model. The results showed that the increase in vehicle speed led to stronger wake turbulent structures. Furthermore, the highest concentration of water in rainy conditions is observed on the front surfaces and specifically on the windshield and headlights. Overall, the numerical results, despite small discrepancies, were found to be in agreement with experimental measurements from the literature. The study concludes that on the one hand, a recirculation region with a strongly three-dimensional, unsteady behavior is produced behind the car and on the other hand, that in conditions of heavy rainfall, functional and aesthetic problems are created in the car. Hence, careful design of EWM (Exterior Water Management) systems is required.

Keywords

Computational Fluid Dynamics (CFD), automotive aerodynamics, DrivAer model, Realizable k–ε, DPM, Polyhexcore.

SIMULATION OF AIRFLOW AND THERMAL FIELDS IN A RECTANGULAR CROSS SECTION PIPE PRODUCED FROM A CURVED VORTEX GENERATOR, WITH AND WITHOUT HOLE, FOR VARIOUS VALUES OF ITS CURVATURE AND HOLE DIAMETER

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ABSTRACT

The subject of thesis that follows is the presentation and investigation of the flow, heat transfer and pressure drop through a pipe with rectangular cross section in which different, each time, Vortex Generators are presented. These Generators are pure solid geometries placed at the base of the pipe in order to accelerate the heat transfer between its inner wall and the fluid area. Each investigation aims to present the respective results that caused from the adaptation of a different VG. The results focus mainly on the efficiency of heat transfer and pressure drop due to the presence of VG. For each section, at the end, the most efficient case of geometry is selected.

Some basic concepts of fluid mechanics are first mentioned, such as the types of flow, the boundary layer, the dimensionless numbers, the pressure drop factor, the heat transfer mechanisms but also the theory around Vortex Generators and how they contribute to the heat transfer along the pipe. The last chapter of the theory will provide an extensive description of Computational Fluid Dynamics, its applications and the various turbulence models that characterize it.

In addition, the presentation of the geometries and grids of the models and the properties applied to them are depicted. Simulations will be performed to study some magnitudes in each of them and will be plotted on charts for better comparison. These steps were implemented, entirely, in the program called ANSYS. More specifically, the geometries were created with "Design Modeler", the creation of the grid were actualized with "Mesh" while the simulations were performed in "Fluent".

The simulations were performed for a constant temperature of the inner pipe walls and of the fluid inlet. About the VG, different cases were considered for its focal angle and hole diameter. In each model, the temperature at the outlet of the pipe, the average Nusselt number of the fluid and the pressure drop (Darcy friction factor) were calculated and plotted in diagrams. Finally, observations and conclusions were explained in each model.

Keywords

ANSYS-Fluent, Heat Transfer, Vortex Generator, Pressure Drop, Nusselt Number

Division of Management and Organization Studies (February 2022)

DEVELOPMENT OF AN EXOSKELETAL PASSIVE SYSTEM FOR THE RELIEF OF THE LOW BACK AREA IN PRIMARY PRODUCTION OPERATION

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ABSTRACT

Musculoskeletal disorders (MDS) related to workplaces in the EU cause economic costs of up to 2% of total EU GDP. The main cause of workplace MSDs is the execution of repetitive tasks (62%), such as carving, which leads to the muscle fatigue accumulation. In recent years, the development of passive exoskeletal mechanisms has been studied, which provide compensatory gravity through springs and / or other elastic parts, which store and release energy, in order to help the workers to perform the appropriate physical movements.

The purpose of this study was to develop an appropriate passive exoskeletal mechanism that will be used by workers in agriculture, who perform repetitive tasks, such as carving tasks, to relieve the low back area and possibly discharge the erector spinae muscle. The effectiveness of the mechanism was assessed by investigating the muscle fatigue accumulation in the low back area.

Figure 1 - Postures using the skeletal mechanism during carving task

The experimental protocol consisted of the video recording of certain markers (Figure 1), which were placed on specific vertebrae of the low back area (S1, L5, L4, L3, L1), during the execution of repetitive carving task. Each participant self-evaluated his fatigue level as Perceptible Fatigue which expressed their discomfort level using Borg's clinical rating scale. The results of the two methodologies were compared with the results obtained from the analysis of a suitable biomechanical model of the low back.

The results showed that the volunteers performed more repetitions when using the exoskeletal mechanism.

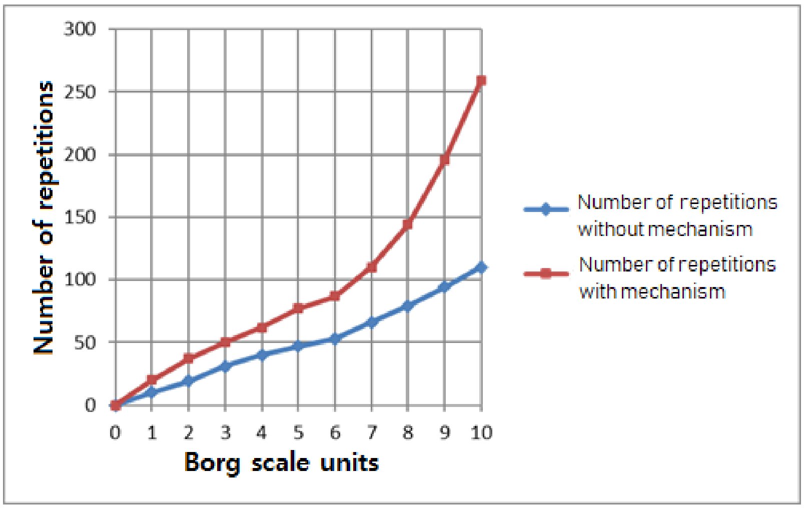

Chart 1 - Volunteer 2, number of repetitions performed as a function of Borg scale number

It was also observed that during the execution of the carving task without the application of the exoskeletal mechanism, most of the volunteers declared ¨very intense¨ and ¨maximum¨ perceptible fatigue (Borg ≥ 7) at about 75% of the total duration of the task in contrast to when they applied the exoskeletal mechanism (65%). This finding is very important because it shows that the use of the mechanism may have led to a reduction in the work consumed by the erector spinae muscle and therefore to the delay of the muscle breakdown. The data were also verified by the results of the biomechanical model where it was calculated that the compression force of the intervertebral disc L5/S1, F' (Nt), decreased by 21% when the exoskeletal mechanism was applied.

Keywords

Exoskeletal mechanism, Muscle fatigue, Borg, Lyapunov

AIRCRAFT MAINTENANCE SCHEDULING USING DYNAMIC SIMULATION

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ABSTRACT

The aim of the thesis is the planning, analysis and optimization of an aircraft fleet maintenance. An effective maintenance system is essential for any company in the aviation industry to achieve the goals it has set. These objectives include minimum cancellations, reduced delays, minimum repair times and efficient use of maintenance resources. In this paper, these objectives will be addressed by the method of dynamic simulation using ExtendSim software. First, an analysis is made of the programming process of an aircraft during its operational cycle. Such maintenance may be either scheduled, when the aircraft or parts thereof have exceeded the specified flight time and maintenance and repair work is required, or unscheduled. The second is when defective equipment is detected or when an aircraft is damaged during a flight arriving at the airport. Then the simulation process is introduced and analyzed in its individual parts. The main objective of the thesis is modelling of the problem and the selection of the data and parameters to be studied. The problem is formulated and hypothetical scenarios that could bring about optimizations in the system are listed. Subsequently, several simulations are performed and the response of the model to both changes in its environment and optimization proposals is analyzed. In addition, the effectiveness of the scenarios and the model itself is presented in terms of sustainability and meeting the objectives of the company.

Keywords

Aircraft maintenance, Simulation, ExtendSim, Modeling, Scenario Manager

CREATION OF A HYBRID RECOMMENDER SYSTEM FOR AIR TRANSPORT WITH THE INTERGRATION OF TEXT MINING TECHNIQUES

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ABSTRACT

The continuous growth of the internet over the last decades has in turn brought αbout decisive changes in the ways of communication, information and the interface between companies and customers. A typical example of such an interface is the field of air transport. Airlines are attempting to target their services to an increasingly large audience. This is an issue that Recommender Systems have to address in order to identify products and services according to the preferences of each user.

In the context of this thesis, therefore, the theory of Recommendation Systems, as well as hybrid Recommender systems is analyzed, while analyzing any weaknesses and problems that arise during their use. In addition, the text mining technique and its applications in the field of data collection are analyzed, and its future is also discussed. Extensive reference is also made to vector space models and especially to the Tf-Idf algorithm which will be used in the paper.

Then, the set of tools and algorithms used to produce the hybrid Recommender System of this thesis is described. Such tools are the dataset containing user ratings for airlines and the algorithms that played a key role in creating the proposed model of the paper. Then, the preliminary work and the methodology followed in the production of this model are described. Two Recommendation Systems were created using two different models in order to finally compare their effectiveness and their ability in terms of the recommendations they predict.

Keywords

Recommender Systems, Air Transport, Hybrid Recommendation Systems, Text Mining Technique, Tf-Idf Algorithm

STUDY OF THE RESPONSE OF RESONATORS FROM LASER PULSE ACOUSTIC STIMULATION

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ABSTRACT

In the present work the responses of type λ / 4 acoustic resonators, (quarter wavelength resonators), a simple tube arrangement with one end closed, are studied computationally, to two acoustic stimuli:

a) in stimulation from a omnidirectional, uniform spectrum, point source to record the frequency responses of the resonators

b) in acoustic stimulation derived from LIB (Laser Induced Breakdown).

LIB is the breakdown of atmospheric air or other gases by appropriately focused short or ultra-short high-energy laser pulses. The optical collapse of the medium is followed by secondary emission phenomena, namely the emission of light and the emission of an acoustic wave in the form of a type N pulse (N-wave, N-pulse), such as those produced by common explosions (sonic booms).

The responses of the Helmholtz resonators, widely used in acoustic applications, are used to compare with the responses of the resonators under study, while for completeness the response of a type λ / 2 acoustic resonator (half wavelength resonator), ie a tube with two ends open, is examined.

The finite element method was chosen for this study, which is one of the most common methods for performing acoustic studies due to its generality, high computational accuracy and reliability of modern software packages. The accuracy of the method is confirmed as, for the Helmholtz resonators, the theoretical central resonance frequency coincides with the resonance frequency in the simulation, and respectively, for the type λ / 4 and λ / 2 acoustic resonators, the theoretical resonance frequencies and their harmonics coincide with those resulting from the simulation.

Finally, the simulations show that the resonators' response to a LIB source results from the product of the resonator's frequency response to the LIB source. This highlights the linear

behavior of the resonator in LIB stimulation, as well as the suitability of the resonators for spectral modulation of laser plasma sources in audio reproduction applications.

Keywords

Helmholtz resonator, quarter-wavelength resonator, half-wavelength resonator, LIB, finite elements method

IMPROVEMENT OF THE PROCESS MANAGEMENT PROCESS

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ABSTRACT

The management of each project is a complex and multifaceted process that is at the core of the required procedures in its implementation, as it ensures its smooth completion and the improvement of the efficiency of the whole and the individual processes. It is therefore a practice whose processes take place not only before and at the beginning of the project, but also during it. Through management, both the schedule and the order of the individual tasks and the project budget can be optimally planned, while the continuous monitoring allows the immediate decision in relation to the required changes and adjustments that may occur.

In this dissertation, the problem of the process of managing a technical project for an existing company that undertakes the execution of technical projects, ie the reconstruction / renovation of existing buildings in order to change their use as commercial stores, is examined. The paper presents the theoretical background of project management, as well as the modeling and simulation of dynamic systems with discrete time processes. Examining how the company completes similar projects, the completion processes of such are examined and a simulation model is constructed accordingly on the EXTENDSim platform. The model is used to determine the average time and cost of processes based on statistical analysis of results, which are verified through a CPM analysis. Finally, in the context of process improvement, a change in the existing project structure is proposed which is also examined through a corresponding simulation model. The results show that the proposed solution significantly reduces both the average time of completion of the project and its total cost.

Keywords

Project management, CPM, EXTENDSim, Discrete time simulation

APPLICATION OF GREY-DEMATEL METHOD TO DETERMINE THE SIGNIFICANCE OF KEY PERFORMANCE INDICATORES OF LEAN REMANUFACTURING

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ABSTRACT

Remanufacturing has been defined as a series of manufacturing steps that affect a component or product at the end of its life cycle, in order to restore it to a condition and performance similar to or better than the new product. Remanufacturing can bring significant economic and environmental benefits, such as cost savings, energy and resource savings and emission reductions since it allows for the continued reuse of products. Remanufacturing combined with lean theory creates an innovative model that supports and promotes the theory of the circular economy. This, has resulted in a global awareness of sustainable production, with remanufacturing gradually becoming a research priority. Key Performance Indicators (KPIs) are management techniques used to monitor businesses effectively and efficiently. KPIs help organizations to understand and measure how well they are performing towards the strategic objectives they have set. To begin with, the objective of this study is first to identify various KPIs of lean remanufacturing and to identify the challenges presented by the uncertainties of remanufacturing. Then, 8 key performance indicators are identified in collaboration with a company active in the remanufacturing sector of aircraft parts. Through interviews with managers and experts of the remanufacturing company, data were collected for the application of the Decision Making and Evaluation Testing Laboratory (DEMATEL) technique combined with the "grey" theory, to determine the significance of the KPIs. The results of the grey-DEMATEL method are presented in a cause-and-effect diagram representing the influence relationships between the KPIs and their influence on the overall remanufacturing processes. The results of this study were discussed with the experts of the remanufacturing company and commented on their validity.

Keywords

remanufacturing, lean theory, Key performance indicators, grey-DEMATEL

TEXT MINING USING THE ORANGE SOFTWARE TOOL

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ABSTRACT

This thesis deals with the applications of machine learning for text recognition and text classification. The development in the field of machine learning and in the field of artificial intelligence and data science is significant and allow, among other things, the automatic processing of large volumes of data, whether they relate to images, videos, audio or texts and extract some valuable information from them. Machine learning allows the recognition of patterns, the recognition of content and the classification of data in such a way that may be of great interest to the researcher. So, data processing is done much faster, something that can benefit research purposes and purposes in various areas of life such as engineering, economics, medicine, security, etc.

In this work we carried out a thorough review of the literature on machine learning and data mining. Then, we focused on the analysis of more specific categories. These are some techniques that are particularly useful in a wide range of procedures related to classification, processing and generally extracting information from texts.

The techniques that mentioned above can be applied in many different ways. There are several softwares that can show good results in a variety of ways, corresponding to what we get by creating code written in a programming language such as python, c++, e.t.c.

One of the software that does not require special knowledge of a programming language is Orange. It is an open source of data visualization and was used in this thesis to do the practical application of the techniques that mentioned above. We have created a model for each case we were considering, which can accept texts in several forms. We will see all these in detail later to this paper. At this moment we must say that we made a reference to other software, similar to Orange, which can show just as good application to similar processes.

Keywords

Machine learning, text processing, text mining, text classification, Orange

WORKPLACE AIR QUALITY AND ITS EFFECT ON THE EMPLOYEES DURING THE COVID-19 PANDEMIC

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ABSTRACT

Tertiary workers have serious health problems, as they are exposed to high concentrations of harmful agents. Harmful factors are categorized into those that come from indoor activities and processes as well as biological agents. The main biological factors that affect air quality are microorganisms, pollen of some flowers and dust. Microorganisms, such as the coronavirus, COVID-19, can cause serious infections in the human body and if the necessary protective measures are not taken, there is a risk of death.

The purpose of this study was to develop, record and analyze the results of an appropriate questionnaire through which the effect of air quality, in particular the biological factor COVID-19, was studied in indoor workplaces as well as in mental health and employee efficiency.

During the development of the questionnaire, emphasis was placed on questions whether respondents were informed/trained about COVID-19 protocols in their workplace, if they came in contact with a confirmed case of the virus and if their workplace was affected by COVID-19. Employees were then asked to answer questions about air quality where they reported their subjective judgment about the temperature and humidity level of the workplace as well as the quality of ventilation. Finally, questions were asked about the feelings developed by the employees, in their workplaces, during the period of the coronavirus pandemic as well as their subjective judgment about the change in their efficiency during the same period.

The results were analyzed with the program "IBM SPSS Statistics" and more specifically Reliability Test, Frequency Analysis and Measure of Central Tendency, Crosstab Report and Chi Square Test, Independent Samples t-Test and Correlation Analysis were applied.

The main findings showed that respondents associated air quality with temperature, ventilation and hazardous microorganisms (COVID-19) but not with humidity in their workplace. Also, the employee's performance in a work environment that may have been contaminated by dangerous microorganisms, such as COVID-19, is affected by the psychological consequences due to the mandatory self-test and the thought that he may work in a workplace where dangerous microorganisms are suspended.

Keywords

coronavirus, workplace air quality, workers’ mental health, employee efficiency, Health and Safety at Work

OPTIMIZATION OF THE DESIGN OF A DISBOND ARREST FEATURE IN CO-CONSOLIDATED THERMOPLASTIC COMPOSITE MATERIALS THROUGH NUMERICAL MODELS

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ABSTRACT

The connection of composites with welding or adhesive is widely used, but this way of connection presents risks as it can lead to catastrophic failure of the construction due to the disconnection. In order the construction to fail safely, additional mechanisms are installed which slow down the spread of the disconnection.

In the present diploma thesis, the design of disbond arrest features of two adherends was optimized using finite element analysis. The adherends were made from a carbon-fiber reinforced thermoplastic composite based on Low – Melt PolyArylEtherKetone (LM - PAEK) matrix, TC1225. The joining method of these two plates was the direct bonding of co – consolidation. To approach the disbond initiation and propagation at the bonding area was used the Cohesive Zone Model (CZM) and were developed numerical models that simulated fracture experiments on four different specimens. The specimens used were the double cantilever beam (DCB), the end notched flexure (ENF), the cracked lap shear (CLS) and the single lap shear (SLS) specimen. A parametric analysis was performed in order to design the disbond arrest features by using rivets on the CLS and ENF specimen. In this analysis for the first specimen were studied the diameter of the rivets for 3 mm, 5 mm ,7 mm and the distance from the beginning of the bonded area which was 10 mm, 20 mm and 30 mm. Also studied the way of placing two rivets in a row, changing the distance between them from 3 mm to 5 mm and 7 mm, in this case the diameter of the rivets was constant at 3 mm and the

distance from the beginning of the bonded area was also constant at 10 mm. For the second specimen were studied the rivets' diameter for 3 mm, 5 mm and 7 mm and the distance from the begging of the bonded area was 10 mm. From these analyzes were exported force-displacement diagrams, failure-displacement surface diagrams as well as distributions of the shear stress zx and the effective plastic deformation.

These results show that the use of these features contributes to the slowing down of the disbonding of the two adherends while at the same time increasing the load-bearing capacity of the bonding.

Keywords

Disbond arrest features, Composite materials, Co – consolidation, Finate elements, Cohesive zone model

DESIGN OF UNMANNED AERIAL VEHICLES

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ABSTRACT

Contrary to conventional aircraft design, the design of Unmanned Aerial Vehicles (UAVs) with Vertical Takeoff and Landing (VTOL) capabilities lacks a standardized, coherent methodology of development. This thesis aims to develop such a methodology for two different configurations and apply it for numerous unmanned aerial vehicle instances of various scales, purposed for aerial firefighting. A literature survey on firefighting aircraft and VTOL UAVs indicates that the water quantities required in firefighting correspond to aircraft of significantly greater size than any non-military drone. The survey also shows that the basis of firefighting aviation is the ability of heavy cargo transport.

These observations function as guidelines for the early conceptual design procedure called "sizing". Sizing refers to the use of mission requirements and statistical data on existing aircraft to approximate the aircraft's weight and size. The procedure is conducted on three scales of each configuration, for payload capacities that collectively range from 100 to 2,000 kilograms. Elements from conventional airplane and helicopter design are combined to initially produce a total of six VTOL, firefighting UAVs of various sizes that use a plethora of propulsion systems.

The configurations studied and sized are the tail-sitter and the multicopter. Tail-sitters are fixed-wing aircraft capable of hovering vertically, with their tail facing the ground, hence their name. Multicopters are rotorcraft powered by more than two lift-generating motors.

The sizing of the electric multicopters results in an extreme scaling rate with respect to endurance, which is confirmed by a direct comparison of a petroleum-powered and an electric large-scale multicopter with the same mission requirements. A brief literature survey reveals that the low energy density of batteries compared to hydrocarbons is the main explanation. Our attempt to further upscale the multicopters for improved firefighting capacity produces a 27-ton quadcopter matching the capabilities of the S-64 Aircrane heavy-lift helicopter.

Each VTOL configuration has its own inherent issues requiring attention. The tail-sitter configuration instigates stability problems during flight, takeoff, and landing, which directly affect tail size and landing gear placement. The multicopters' entirely vertical operation is highly energy consuming, leading to increased weight.

Keywords

Tail-sitter, vertical takeoff and landing, unmanned aerial vehicles, design, multicopters.

NUMERICAL THERMOMECHANICAL ANALYSIS OF A LIQUID HYDROGEN SPHERICAL STORAGE TANK

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ABSTRACT

In this study a numerical thermomechanical analysis of a hydrogen fuel storage tank is performed. The first section presents the advantages and difficulties of replacing kerosene by air transport and the ways that hydrogen will be used by aircraft. For the thermal and mechanical analysis, an aluminum tank is selected, spherical in shape, while the fuel is in liquid form. Due to the large temperature difference of the fuel with the external environment, the need for increased insulation specifications is created. The way the tank is designed to operate successfully in cryogenic conditions is analyzed. The ANSYS finite element package is used for mechanical analysis. STATIC STRUCTURAL analysis was used for the parametric study of tank loads. First, the difficulties faced by the model in the discretization are explained, due to the complex geometries. They are also explained the boundary conditions imposed on the model for the more accurate simulation of the realistic conditions. The validation of the original model is followed by series of tank models with different loads and in different operating environments. In addition, geometric modifications are made that contribute to the mechanical upgrade of the construction. The analysis includes the distributions of the maximum principal stresses for each structure of the cryogenic tank. The safety margins are calculated in terms of breakage with a safety factor of 1.5 and in terms of leakage with a safety factor of 1.1. these are the typical values for aeronautics. The temperature distribution is also presented in the presence of insulating material as well as the difference in the intensive state with and without thermal loads.

Keywords

ANSYS, hydrogen, cryogenic tank, finite elements

PREDICTION OF THERMAL CONDUCTIVITY OF GRAPHENE - BASED ADHESIVES

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ABSTRACT

Polymeric composites, during the last couple of decades, have been widely studied, hugely improved and advanced as it comes to their mechanical, thermal and electrical properties. This has resulted to them being widely used not only in the automotive and aerospace industry, but in every-day items too. While fiber-reinforced polymers and laminates are the most commonly used composites, in the last years, inclusions in the nano-scale have been considered as a great alternative to the more typical inclusions, as they combine great intrinsic thermal properties with more-than-decent mechanical properties.

Heat transfer has recently become one of the most important research fields for the design of polymer composites, since the electronic components are constantly becoming faster, lighter and more power-dense, cramming loads of computational power in as little physical space as possible. This creates the need for superior materials that manage to dissipate greater amount of heat per volume. So, the polymeric nano composites provide a great opportunity for the design of the appropriate material for each use, as there is a great number of variables that contribute to the final properties of the material such as: the type of the fillers, their physical properties, their content in the composite, the processing and manufacturing method of the composite.

However, there is a great amount of effort involved when it comes to developing such materials since there is no way to know a priori their effective thermal conductivity. This creates the need of having to physically make and measure a great number of materials until the required properties are achieved. That is the problem that this work tackles. More specifically, the goal of this work, is to predict the thermal conductivity of polymeric nano composites.

The first idea was to utilize an analytical micro mechanical model. After examining the previous research work, the model of Nan [1], was chosen since it is fairly complex and considers many of the parameters that affect the thermal conductivity of the composite.

Although promising, the model did not converge with the experimental data from [2] (which is the benchmark for this thesis). Since no other promising analytical models were found, the construction of a numerical model with a Representative Volume Element (RVE) of the composite, was the next reasonable option.

At first, the DIGIMAT FE software was utilized but due to its limitations when it comes to discretizing the RVE and also due to its inability to run parametrically, the decision of constructing the model via a custom Python script using ABAQUS, and simulating Carbon Nano Tubes (CNTs) instead of Graphene Nano Platelets was made. The different choice of particles was made due to the less complex geometry of the CNTs. To overcome various challenges regarding the required periodic geometry of the RVE and its meshing, a series of powerful tools were developed that add to the functionality of ABAQUS in a way that they can be used in many different applications (not limited to RVEs and composites, but to actually mesh any complex geometry). The model showed great results and converged with the experimental data of [2]. Through this work and the current thesis, a very interesting discussion is made on whether the vision of a model that can predict the thermal conductivity of a particulate polymeric nano-composite is attainable.

composite is attainable.

Keywords

Thermal conductivity prediction, Composite, Abaqus, Digimat

A COMPUTATIONAL INVESTIGATION OF AN ELECTRIC ENERGY HARVESTING SYSTEM FROM NONLINEAR VIBRATIONS OF PIEZOELECTRIC BEAM IN BUCKLING CONDITIONS

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ABSTRACT

In this particular thesis, the design of various computational models is performed in order to study the harvested power from the piezoelectric elements. In the first part of the assignment, which constitutes the theoretical background, reference is made to the development of composite and piezoelectric materials and how we, in turn, can utilize them to energy harvesting from environmental oscillations. In addition, we focus on the piezoelectric effect as it is a promising technological field. Then, the mathematical model and the numerical equations on which we are based for the analyses, are analytically presented. Closing the first part, reference is made to the bistability, and the phenomenon of buckling and the post-buckling area that will be used in the majority analyses are explained.

The numerical simulations are performed for a composite beam which is modeled by using 9-node finite elements of the Lagrange family. The experimental specimen, which will be considered as prototype for the needs of the work, is subjected to axial compressive loading by changing various parameters each time, such as the addition of mass, the change of thickness, the type of support and the number of piezoelectric materials. The aim of the thesis is the regulation of the individual parameters of the investigated configuration, maximizing the electric energy harvested from the vibrating structure.

Keywords

Energy harvesting, Bistability, Piezoelectric materials, Composites materials, Buckling

SYNTHESIS AND EXPERIMENTAL CHARACTERIZATION OF A BIO-BASED RESIN ENHANCED WITH GRAPHENE NANOPLATELETS

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ABSTRACT

This thesis is a study of the effect of reinforcing a biological base resin with Graphene Nanoplatelets (GNPs). Graphene is known for its extremely high mechanical properties and especially for its Young's modulus (~ 1 TPa) and tensile strength (~ 130 GPa) and its beneficial effect on the properties of a polymeric matrix has been repeatedly confirmed. However, a necessary condition for the upgrade of the properties of the composite is the compatibility of matrix and reinforcement and the correct manufacturing process, as otherwise there is a case of degradation of the final properties. Thus, in the present work, the material is synthesized and an experimental study of the change of the mechanical properties of the resin is performed through tensile and fracture experiments in order to obtain results on the compatibility of the two materials, the correctness of the manufacturing process and the effectiveness of the reinforcement.

First, the process of making the samples of neat and reinforced resin is presented and then the experimental procedures and results are presented, as well.

Tensile experiments provide information about the effect of reinforcement on the Young's modulus, the tensile strength and fracture strain of the material for contents of 0.5%, 2% and 3%.

Respectively, through the three-point bending fracture experiments, conclusions are drawn about the change in material fracture toughness and fracture energy release rate for contents of 0.5%, 1% and 2%.

Then, the experimental results of tensile strength are compared with results obtained for the material through modelling, while then the suitability of the resin as an adhesive in structural or decorative applications is checked by comparing the properties of conventional reference adhesives.

Finally, the life cycle of the resin is analyzed and six environmental impact indicators are compared with the corresponding indicators of a conventional resin to assess the environmental cost of the bio based resin.

Keywords

Biomaterials, Composite materials, Epoxy resin, Graphene, Tensile test, Fracture test

CATHODIC PROTECTION OF OFFSHORE METALLIC STRUCTURES

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ABSTRACT

In this thesis, a mathematical formulation of the cathodic protection problem is made in which the system is divided into three main areas, the anodes in the seawater-environment and the cathodes, then the main physical quantities that will concern us for the modeling of the problem are mentioned. These physical quantities are current density, electrical conductivity and electrical potential. The Laplace equation governing the phenomenon is then solved by the finite element method and with the assistance of appropriate software. In the last stage, the most useful diagrams are represented in order to establish the suitability of the cathodic protection mechanism

Keywords

current density, electrical conductivity, electric potential, Laplace equation, Boundary elements method

DEVELOPMENT OF BIS-MALEIMIDE BASED SELF-HEALABLE STRUCTURAL COMPOSITE MATERIALS

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ABSTRACT

In the current work, a comprehensive literature review that deals with novel technologies that are related to applied mechanics and aeronautic domain is provided. More precisely, this investigation focused on the development of high- performance and self-healable composite materials. Self-healable materials are described in detail while appropriately classified according to healable system incorporated within the host matrix having an aim to repair potential defects that will be future created, during their service life. Melt electro-writing process (MEW) technique is a method that is utilized for the fabrication of fibrous structures. In the current work, MEW was utilized as a novel method for selfhealing agent (SHA) incorporation within composite structure. MEW experimental process parameters are also described and the influence of them to the final composite is also discussed. Furthermore, different types of self-healable composites that are tested under mode I and II loading conditions are also reviewed and further discussed.

In the present investigation, self-healable carbon reinforced plastics (CFRPs) were manufactured by MEW. More precisely, SHA that is based on thermo-reversible Dielsalder reaction mechanism (nano-modified or not by graphene nanoplatelets, GNPs) was successfully incorporated into composites' structure. After manufacturing process, the fabricated CFRPs were tested under Mode I and Mode II loading conditions while the tests were repeated after the activation of the healing cycle. In addition, three-point bending (3PB) tests were performed to investigate the effect of the SHA incorporation on the inplane mechanical properties of the CFRPs. Based on experimental results, the modified CFRPs exhibited significantly improved interlaminar fracture toughness properties with GNP modified ones to present the best toughening performance. After the activation of the healing process the CFRPs were able to partly restore its mechanical properties while no significant degradation effects were observed according to 3PB tests.

Keywords

composite materials, self-healing of materials, melt electro- writing process, bis- maleimides, mode I testing, mode II testing, graphene nanoplatelets

MODELING OF GRADED PARTICULATE COMPOSITE MATERIALS

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ABSTRACT

Composite materials with graded structure and/or with graded composition is of special interest in many different research areas such as bioengineering, tribology, optoelectronics, fracture mechanics, and nanotechnology. The present work deals with the development and application of a rotational technique for the manufacturing of Aluminum- Epoxy particulate composites with graded filler concentration. For that purpose, customized molds were manufactured from PMMA (plexiglass). Specifically, a disk was designed and manufactured to fit a pre-existing centrifuge rotor with adjustable revolutions per minute (RPM). Next, to study the effect of the filler concentration radial variation on the dynamic properties of the graded composites, Dynamic Mechanical Analysis (DMA) measurements were conducted. Using the DMA test results, the variation of the dynamic properties E', E'', tanδ with temperature, vibrational frequency as well as rotational frequency, filler volume fraction and radial distance are presented and analyzed. Finally, for the better understanding of the obtained experimental results, the SDM Model developed in collaboration with Professor G. C. Papanicolaou was successfully applied for the description of the results.

More precisely, the aim of this thesis was to study the change in the filler-volume fraction V_f as a function of the radial distance, r, from the center of rotation and the frequency f' using an experimental centrifugal rotating disk device. Also, the ratio of the storage modulus E'/E'_{max} was studied as a function of the volume fraction V_f and the frequency f' for various distances r.

The results were described using the Sigmoid Degradation Model (SDM) which correlates the gradation of properties (such as the storage modulus E') as a function of radial distance, temperature and frequency of rotation f'.

Due to the huge amount of results, in this thesis we analyzed 3 specific cases. In the 1st case, we studied the behavior of the ratio of the storage modulus E/E'max as a function of the frequency f' at various temperatures for r=86 mm & 98 mm. In the 2nd case, we analyzed the ratio of the storage modulus E'/E'_{max} as a function of the volume content for various

temperature values for r=86 mm & 98 mm was studied. In addition, the ratio of the storage modulus E'/E'_{max} as a function of the volume fraction (Vf) for various temperature values for r=86mm and r=98mm was studied. Finally, In the 3rd case of this study, the behavior of the ratio of the Vf/Vf_{max} as a function of the rotation frequency f' at various distances r was also studied

The experimental results as compared to the theoretical ones derived from the SDM model, showed that the SDM model provides a useful tool for the description of the change in both the storage modulus E' as a function of V_f and f' for various temperature values and the volume fraction V_f as a function of f' for various distance values r.

Keywords

Polymer Composite Materials, Graded materials, Particulate Composites, Sigmoid Degradation Model, Storage Modulus

INVESTIGATION AND NUMERICAL MODELLING OF BUCKLING AND POST-BUCKLING ANALYSIS OF METALLIC STIFFENED AIRCRAFT PANELS

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ABSTRACT

The fuselage of conventional modern aircraft consists of a thin shell that is stiffened in the longitudinal and vertical directions with thin-walled structures. Depending on the position of the stiffened panel on the fuselage, the panel could be subject to compression, shear and bending loading, as well as lateral internal pressure due to the pressurized cabin. The stiffened panels that are subject to combined compression and shear are of particular interest, since buckling phenomena may occur. Buckling may be destructive for a structure, depending on its ability to carry additional loads in the post-buckling region, that is the region after the first buckling phenomena occur on the structure. Using the finite element method and the parametrical code ANSYS APDL, this diploma thesis investigates the numerical modelling of buckling and post-buckling behaviour of aeronautical structures, which can be flat plates, stiffened flat plates, shells and stiffened shells. Numerical modelling investigation includes the selection of element type, mesh size, initial imperfections and number of substeps/iterations for the non-linear analysis. Numerical model codes are employed and verified/validated with comparison to experiments or numerical models found in bibliography, with the purpose of predicting the total buckling behaviour of these structures. The total buckling behaviour includes the prediction of local buckling of the skin and stiffeners, global buckling of the structure, failure of the structure, as well as the corresponding loads at which these buckling phenomena occur. Among the purposes of the numerical modeling procedure is the parametrization of all the geometrical characteristics, material properties and boundary conditions, so that the models can be adjusted as needed. In addition, the buckling behaviour of isotropic and orthotropic stiffened shells subjected to combined compression/shear loads is investigated for the purpose of extracting the load interaction curves and comparing them. The diploma thesis demonstrates that the numerical models can predict the buckling behaviour of aeronautical structures with satisfying accuracy, without the introduction of complicated, tedious non-linear phenomena in the analysis, completing all the parametrization goals. Last, it is shown that orthotropic stiffened shells are more sensitive to buckling due to shear loading, compared to the corresponding isotropic stiffened shells.

Keywords

Stiffened fuselage panel, Parametrical numerical analysis, Combined buckling under compression/shear, Load interaction curves, Non-linear buckling analysis

ULTRASOUND PROPAGATION THROUGH 3D PRINTED SCAFFOLDS FOR OSTEOPOROSIS DIAGNOSIS

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ABSTRACT

The use of ultrasound is widespread in many fields of research, such as in biomechanics where osteoporosis is studied through the propagation of ultrasound in cancellous bone. The present work studies the effect of the characteristics of ultrasound and in particular the backscatter factor on the architecture and material of the cancellous bone, using 3D-printed trabecular bone models.

3D printing is an innovative method of prosthetic construction in which objects are made through the successive addition of overlapping layers of material. This technology is capable of manufacturing functional physical components with or without porosity by depositing layer-by-layer materials using 3D computer models. Therefore, it facilitates the production of advanced bone scaffolds as the main purpose was to make bone-like copies with the most accurate structure possible, following the same printing methods for all samples, to ensure that the results and conclusions concern only the material influence on ultrasound properties.

Initially, spongy bone copies were fabricated by a 3D-printer from two different printing materials, polylactic acid (PLA) and thermoplastic polyurethane (TPU). Ultrasound propagation experiments were then conducted to draw conclusions about the structure of the specimens. Specifically, focus and unfocus transducers were used to estimate the backscatter coefficient as a function of density as it has been shown to depend on the structure of the material. The measurements were compared with the two types of transducers, in order to investigate whether there is a correlation between the results and to draw useful conclusions for the accuracy of the focus mutants.

3D-printed scaffolds cannot be compared to real spongy bone, especially if it is osteoporotic. Nevertheless, useful conclusions emerge in relation to the properties of ultrasound and its correlation with the internal structure of the material and in particular with the structural degradation caused by the aging process. Thus, further research may help to develop better diagnostic devices for osteoporosis.

Keywords

Ultrasound, scaffolds, osteoporosis, 3-D printing, polylactic acid, thermoplastic polyurethane

MODELING, SYNTHESIS AND EXPERIMENTAL CHARACTERIZATION OF A BIO-BASED RESIN ENHANCED WITH NANOCELLULOSE

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ABSTRACT

In the present thesis, the synthesis of bio-based cellulose nanocrystals (CNCs)/epoxy composites was studied.

The resin that was used is EnviPOXY 530 (Spolchemie) and is derived from epichlorohydrin. Epichlorohydrin is produced from the plant-based glycerin. The hardener of the resin is an aliphatic amine. That means that, the adhesive is based on the ingredients of epichlorohydrin and bisphenol A and therefore is not a fully bio-based adhesive. Finally, cellulose nanocrystals were used as reinforcement, which can be isolated from cellulose fibrils or from cellulose derived from bacteria. The cellulose nanocrystals that were used are produced by the company named "Nanografi Nano Technology".

The first stage is about the construction part. More specifically, the work includes the laboratory synthesis of the adhesive and the construction of adhesive samples. This process included the conduction of a parametric study of the curing temperature and the residence times of the material in the various stages of degassing, mixing, dispersion of nanocrystals and curing.

The second step concerns the experimental characterization of the adhesive. For this purpose, tensile and fracture toughness tests were performed on bulk adhesive specimens. Also, the adhesive was reinforced with cellulose nanocrystals in three different contents of 0.5%, 1% and 2% by weight to examine the enhancement effects of a bio-based reinforcement.

The experimental results showed that the bulk adhesive has a Young's modulus of 3.29 GPa, a tensile strength of 45.15 MPa, a stress intensity factor of 0.61 MPa $*m^{1/2}$ and a critical strain energy release rate (GIc) of 0,091 KJ/m^2 .

The addition of cellulose nanocrystals in the epoxy resin didn't improve the mechanical properties of the neat resin. More specifically the maximum decrease in the Young's modulus was 33.5% for the content of 0.5% w/w, while the maximum decrease in the tensile strength was 5.8% for the content of 2% w/w. The maximum decrease in the factors KIc & GIc was 5% and 9.6% in the content of 0.5% w/w respectively. These results were due to the presence of intense aggregation of cellulose nanocrystals in the adhesive due to their polar nature.

After the experimental results and their comparison with the average value of the respective properties of commercial adhesives, we came to the conclusion that the bulk adhesive can be used as adhesive of decorative applications and under some cases as an adhesive of structural applications. In respect of reinforced adhesive, it can also be used in decorative applications but not in structural applications, except in cases where the requirements of the adhesive in terms of stiffness and the propagation of cracks are limited.

Finally, due to the urgent need to control the environmental impact of new materials, a Life Cycle Assessment (LCA) was conducted in accordance with ISO 14040 where six potential indicators were calculated: the potential for depletion of abiotic resources, the potential for acidification, the potential for freshwater eutrophication, the potential for ozone depletion, ozone, and the potential for global warming. The comparison of potential values with a commercial epoxy resin whose data were obtained from the literature showed that the bio-based adhesive and the enhanced resin has a low environmental footprint.

Keywords

Cellulose, cellulose nanocrystals, bio-based epoxy resin, mechanical properties, environmental impact

NUMERICAL THERMOMECHANICAL ANALYSIS OF A LIQUID HYDROGEN CYLINDRICAL STORAGE TANK

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ABSTRACT

The aim of this work is the numerical thermomechanical analysis of a cylindrical liquid hydrogen fuel storage tank. More specifically, the modes of operation and the execution of the model in a programming environment are analyzed, while then a parametric analysis of the tank is carried out to find extreme values of this operation. In each of the sections there are figures and summary tables for ease of reading and understanding. In particular, the first section presents introductory data on hydrogen as a fuel. Reasons why aviation is turning to the use of hydrogen. Its efficiency and environmental footprint compared to other fuels already mentioned in this field. Then the requirements that must be supplied by liquid hydrogen and the types of tanks that can support this function are mentioned. The geometric characteristics and dimensions of each part of the tank are presented. The materials used for each of these sections, with their thermomechanical properties. Here is an introduction to discretization and in particular the discretization of the tank system. The type of elements, their total number, and the modeling of the connections between the parts of the tank. Boundary conditions and their correlation in the programming environment, ways and means of their modeling are analyzed. Upon completion of these, the thermomechanical results from the analyzes are presented, such as the maximum stress, temperature, and heat flow distributions. In the last analysis section, a parametric thermomechanical analysis of the liquid hydrogen fuel tank is carried out, to find extreme values of its operation and ways to improve the existing arrangement. Finally, the conclusions section collects observations and comments on the analyzes as well as suggestions for future research.

Keywords

LH2, hydrogen, cryogenic tank, finite elements, cylindrical tank, model, analysis

MULTI FIDELITY AEROELASTIC ANALYSIS OF HIGH ASPECT RATIO AIRCRAFT WINGS

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ABSTRACT

In the foreseeable future, the rapid rise in aircraft travel demand will induce several environmental threats. On that front, the European Union envisages a 75% decrease in CO_2 and NOX emissions in the atmosphere for future commercial transport aircrafts. Key enabler for this effort is the introduction of novel, more efficient airframe designs with improved aerodynamic as well as structural efficiency. Regarding the aerodynamics, increasing the aspect-ratio of a wing is a well-established practice for increasing the aerodynamic efficiency by reducing the induced drag, which in turn improves fuel efficiency. As far as the structure is concerned, the introduction of composite materials in the design process results in lighter yet stiffer configurations. Nevertheless, such configurations are prone to certain phenomena, the most prominent being the elevated flexibility of the wing that on one hand induces a material and/or geometric nonlinear behavior and on the other hand a closer coupling between the structure and the surrounding fluid, aggravating static and dynamic aeroelastic phenomena. Furthermore, accounting for this type of phenomena requires sophisticated analyses, which in turn are bound by the associated, often prohibitive, computational time, hence they are preferred only for the later design stages of an aircraft structure. Aiming to alleviate the aforementioned issues, low-to-medium fidelity tools are often utilized early on the design stages, albeit suffering from reduced accuracy and inability to capture higher-order phenomena that might be present. This thesis aims to identify in detailed fashion the differences between the various fidelities of the numerical tools present and investigate the static aeroelastic behavior of a contemporary transport aircraft wing, namely uCRM13.5, a modified high aspect ratio version of the original Common Research Model (CRM) developed for very flexible wing design studies. As a preliminary study, the accuracy of two numerical CFD solvers of low and high-fidelity, are investigated via the transonic ONERA M6 wing case study. A convergence study with various computational grids of increasing size is conducted along with an influence analysis regarding the selection of the turbulence model as well as the first cell wall distance (Y+), necessary feature for capturing the boundary layer using RANS turbulence models. The resulting pressure coefficients at various spanwise sections of the wing are compared to their corresponding experimental ones as well as the lift, drag and moment coefficients are compared to those from NASA's wind simulation. Having examined the results of the case study and having comprehend the methodology used, grid convergence studies are also conducted with the low and high-fidelity aerodynamic solvers for the uCRM wing with 13.5 aspect ratio in order to find the optimum CFD grid and to carry out the aeroelastic analysis. So, as a final step, the CFD obtained pressure field is applied to the structural FEM mesh of the wing, with the resulting displacements and stress field constituting the quantities of interest for the structural analysis.

Keywords

Computational Fluid Dynamics, Fluid-Structure Interaction, ONERA M6 wing, NASA Common Research Model, Static aeroelasticity.

DIVISION OF DESIGN AND MANUFACTURING (JUNE 2022)

ROBOTIC MACHINING OPTIMIZATION USING DIGITAL TWINS

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ABSTRACT

The use of industrial robots for machining operations has attracted the attention of many industries lately, as they are able to significantly increase the production system flexibility and reduce the production cost, while present several advantages over conventional CNC machines. However, several challenges have slowed down the adoption of robots in machining tasks by industry. Industrial robots are constructed as serial, open kinematic chains, leading to insufficient structural stiffness, which in turn directly affects the machining process accuracy. In addition to this, due to the posture dependency of the robot dynamic behavior, time consuming and costly experiments are required to determine its dynamic behavior over its whole working space with traditional approaches. For this purpose, this work aims to develop a complete Digital-Model for robotic machining that can be used during the process planning stage, providing a tool for virtual commissioning of the process. For the robot arm modelling, the flexible links-flexible joints approach has been selected and the Multi-Body Simulation method combined with a Component Mode synthesis method has been adopted for the simulation of its dynamic behavior. The cutting tool deflections due to robot deformation during the process can be calculated with this model too. Additionally, motivated from the tremendous flexibility and versatility of robotic based machining systems two optimization algorithms have been developed, in an effort to increase process accuracy and efficiency. Specifically, an algorithm that calculates the workpiece optimal placement position with respect to robot stiffness has been developed, acquiring knowledge from the robot stiffness maps we generated using the above-mentioned model. Also, an algorithm calculating the optimal feed-rate of the robot arm during the machining process has been developed, attempting to constraint the contour error by regulating the generating cutting forces without affecting the productivity. Finally, the developed model and algorithms have been applied in two different case study parts to present their capabilities and functionality. Results showed that with the application of the two developed optimization algorithms the process accuracy can be improved up to 45%, compared to the unoptimized process setup.

Keywords

Robot Machining, Multi-Body Simulation, Digital-Model, Workpiece Placement Optimization, Feed-Rate Scheduling

COLLISION DETECTION OF A ROBOTIC ARM BASED ON STATISTICAL TIME SERIES METHODS: A COMPARATIVE STUDY

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ABSTRACT

This study explores the detection of collisions on a collaborative robotic arm (cobot) under different Case Studies that correspond to distinct robotic tasks using statistical time-series methods. The collisions cause abrupt changes in the investigated torque and force signals acquired from the test rig, and two unsupervised and one supervised method are postulated for the effective and early detection of them. The postulated methods are three, namely the variance-based, the wavelet-based (supervised) and the RAR model-based, which are comparatively assessed with each other, as well as with two state-of-the-art methods, namely the residual-based and the FFT-based (supervised), in terms of True Positive Rate (TPR), False Positive Rate (FPR) and Detection Delay Time (DDT). The three case studies investigated are based on the measurements and the results of previous works that use the same KUKA LWR4+ robotic arm and they include either the autonomous motion of the robot in the first two Case Studies or the physical collaboration between the human and robot in the third Case Study. The collisions are of different nature along the different Case Studies, with varying magnitude and direction. The results indicate great TPR via all three postulated methods, that outperform the state-of-the-art ones, while all methods have zero FPR. Regarding detection time, each method has better performance in a different Case Study, with the RAR model-based being the fastest overall, followed by the wavelet-based and then the variance-based one.

Keywords

Collision detection, statistical time-series, comparative study, robotic arm

DAMAGE DETECTION ON AN OPERATING WIND TURBINE BLADE THROUGH THE USE OF MULTIPLE PSEUDO-INPUT MODELS AND THE HYPERSPHERE METHOD

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ABSTRACT

In the present thesis the problem of damage detection on an operating wind turbine blade via the usage of stochastic vibration signals under natural excitation is considered. The trend towards the construction of ever-larger wind turbines has highlighted the importance of automating the monitoring of their structural integrity and therefore the use of robust damage detection methods is deemed necessary. In this context, two methods are proposed based on the modeling of the blade dynamics using Multiple-Input Single-Output Transmittance Function models and the representation of a healthy subspace with Hyperspheres of appropriately selected dimensions. The former are potentially robust to the large uncertainty presented in the structure through the varying environmental conditions that can mask or be confused with damages and make their detection with conventional methods very challenging. The effectiveness of the methods is examined through their ability to detect three artificially induced crack-type damages 15 cm, 30 cm, and 45 cm in length, on the blade's trailing edge. The results, based on a systematic assessment via 3 000 test cases and training with only 100 healthy signal sets, indicate that four sensors are adequate for achieving excellent detection performance reaching almost 100% True Positive Rate (TPR) for just 1% False Positive Rate (FPR) for the 15 cm crack damage scenario and for 0% FPR for the 30 cm and 45 cm damage scenarios. Finally, an analysis is made on the sensitivity of the proposed methods in terms of changing their various parameters and the drastic increase in efficiency compared to other methodologies that have been applied in the past for the same problem is presented.

Keywords

Wind turbine, Structural Health Monitoring, ARX modeling, Hypersphere Method, Environmental uncertainty

DEVELOPMENT OF A METHOD FOR GENERATING AND USING SYNTHETIC DATASETS FOR ARTIFICIAL INTELLIGENCE APPLICATIONS IN MANUFACTURING SYSTEMS - APPLICATION IN VISUAL RECOGNITION

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ABSTRACT

The use of intelligent systems to improve manufacturing processes is the basis for the development of automation and quality inspection solutions in Industry 4.0. Artificial Intelligence (AI) applications based on Machine Learning (ML) methods are widely accepted as promising technologies in manufacturing. However, ML techniques require large volumes of quality training datasets and in the case of supervised ML manual input is usually required for labelling those datasets. Such an approach is expensive, prone to errors and labor as well as time intensive, especially in a highly complex and dynamic environment as those of a production system. Synthetic datasets can be utilized for accelerating the training phase in ML by creating suitable training datasets as well as by automatic labelling via the simulation tools chain and thus alleviating user's involvement during the training phase. These synthetic datasets can be enhanced and cross-validated with real-world information which is not required to be extensive.

The objective of the thesis is to evaluate the performance of ML approaches such as Convolution Neural Networks when trained upon synthetic datasets. Four industrially relevant cases will be examined: a) a classification task, b) a color detection task c) an object detection task for robotic control and d) object detection task for quality inspection. Different ML models have been selected and evaluated on a set of actual data, in this case a set of images taken from the real environment.

Keywords

artificial intelligence; synthetic datasets; machine learning; computer vision; object recognition

APPLICATION OF ARTIFICIAL NEURAL NETWORKS IN ELEVATOR TRAFFIC ANALYSIS

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ABSTRACT

The trend of constructing high-rise buildings in the world today has led to a demand for better vertical transportation services. As elevators are the main transportation facility in buildings, the system that controls them must maximize their transportation capacity and improve the quality of passenger service. The most basic regulation of elevator systems in multi-storey buildings is sectoring. In the context of this work, the possibility of optimally defining service sectors (sectors) of an elevator system during the exit traffic phase of the building was investigated using Artificial Neural Networks (ANNs). The theoretical analysis and its application in individual cases (case studies) showed that the hypothesis becomes feasible as the Artificial Neural Networks give in a very short time optimal or sub-optimal solutions with a relatively small error.

Keywords

Artificial Neural Networks, Elevators, Sectoring, Waiting Time, Vertical Transportation

A HIERARCHICAL APPROACH FOR SIMULATION-BASED DIGITAL TWIN OF AN ENTERPRISE

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ABSTRACT

In a factory, work scheduling is a demanding and time-consuming process. More specifically in the food industry, where the raw material is a seasonal product, the need for the smooth operation of production units is critical. Production engineers are responsible for the proper and continuous operation of the factory, the machines and the necessary personnel that will be used during the production period. In the case that the factory beyond discrete parts also has continuous parts, the planning of the work becomes particularly difficult and approximate methods are used. Now, this problem has been solved to a large extent thanks to special production system simulation packages. Engineers have the ability to control the production process, make changes - modifications with the aim of improving the productivity of the factory. In this thesis, the detailed recording of the production process of a factory producing tomato products is presented and analyzed. Therefore, data was collected from all the individual departments of the factory, in cooperation with the production engineers of the factory. This data was digitally processed and entered into the simulation software in order to design the digital simulation models, run operational scenarios and propose possible solutions to improve the production processes. In addition, simulation models will facilitate production engineers to proceed with the full digitalization of the factory under the framework of the 4th Industrial Revolution. Therefore, the developed simulation models will be properly parameterized to act as models for monitoring, predicting and improving production lines.

Keywords

Food Industry, Manufacturing Systems, Discrete Event Simulation, Modelling and Industry 4.0

FEA SIMULATION OF HIP FRACTURE TREATED WITH ROD-SCREW FIXATION AND DESIGN OF ROBOTIC SURGERY TRAJECTORY

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ABSTRACT

Hip fracture rehabilitation is not always successful and many individuals experience pain, disability, and reduced quality of life afterward. So, continuous emphasis should be placed on optimizing the surgical procedure and minimizing the risk of complications. Furthermore, Computer-Assisted Surgery (CAS) is a developing method of integrating robotic technologies in the operating room improving the accuracy and efficiency of the operation. So, this thesis has an emphasis on evaluating, through FEA, a new method of DHS insertion, and the design of a manipulator's control system for the prosecution of it.

Rotation of femoral head fracture during the operation of DHS insertion, due to screw's frictional forces, is a subject of interest for surgeons because it leads to fault attachment of the two fragments. A new approach to surgical operation is proposed and studied in the first part of the thesis. This method's distinguishing feature, compering with the conventional one, is the application of a traction force to the screw prior to its rotation, which causes the bone fractures to come in contact and develop frictional forces. The sliding distance between the two fragments and the internal stresses of the bones are evaluated concerning the validity of the method.

In the second part of the thesis, the Kuka IIWA manipulator was selected to simulate the operation via the Simulink block diagram environment. Upon completion of the screw's finite element analysis, obtained values of forces and velocities, as well as reaction forces of the screw during the tightening, were used for the Kuka simulation. Kinematic and dynamic principles were implemented for the design of the controller. Finally, the result of joint torques and the end-effector's position and forces were assessed for the validity, and the perspective of the system to be integrated into an actual surgery room.

Keywords

Computer-Assisted Surgery, Dynamic Hip Screw (DHS), Finite Element Analysis, Ansys Mechanical, Manipulator, Simulink, Force-Motion Hybrid Control Kuka IIWA.

AL-DRIVEN PRODUCTION SCHEDULING BASED ON MULTI-AGENT SYSTEM

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ABSTRACT

Mass production industries and global firms depend on production management in order to compete in the modern volatile manufacturing marketplace. Achieving high manufacturing performance requires a compound of AI services and information technologies working in parallel across different business layers and ensure information transparency and precise decision-making. As research and innovation took off, an ecosystem of smart autonomous assets (so called agents) has been introduced in all manufacturing levels constructing the main idea behind Industry 4.0. With Multi-Agent Systems (MAS) appearing in the forefront of nowadays manufacturing research and innovation, the requirements of interoperability and granularity is the primary challenge for I4.0 stakeholders. The realization of this objective is found in the core components of I4.0, so called Asset Administration Shell (AAS), which provide abstraction in the production assets description and interactions. As a result, managing to design and develop AI services with increased abstraction in the applied environment enables the deployment of increased automation and flexibility in the business operations. This thesis focuses on exploiting AAS technology for the design and development of a scheduling meta-agent that uses AI in order to solve different production schedule optimization problems. For that reason there was proposed a toolbox of three independent AI agents, that act as a plugin to the meta-agent interface and allow decision-making in three different scheduling problems namely factory, logistics, and conveyor scheduling. (a) The development of the factory scheduler plugin a heuristic decision-making algorithm for scheduling was utilized; (b) for Logistics scheduler was based on a mathematical optimization problem that uses Fuzzy Logic and is solved by a Genetic Algorithm; (c) while for the Conveyor scheduler there were used both a Mixed Integer Programming model and two Machine Learning model (LSTM RNN, and a FFNN). The MAS was deployed in two different manufacturing cases i.e. automotive and bicycle manufacturing industries demonstrating improvement in the business KPIs. In overall, the MAS was proven efficient in the ability of managing the production environment with low human interference required.

Keywords

Production Scheduling, Multi Agent System, Artificial Intelligence, Metaheuristics, Machine Learning

VIBRATION-BASED UNSUPERVISED DAMAGE DETECTION ON AN OPERATING WIND TURBINE USING MISO-ARX TRANSMITTANCE FUNCTIONS AND MULTIPLE MODEL BASED METHODS

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ABSTRACT

Present thesis attempts structural health of monitoring in a Vestas V27 wind turbine blade, via Stochastic Time Series method under real operating and environmental conditions. Random stochastic acceleration measurements are acquired from 12 accelerometers placed in separate positions on the blade over a three-month period. The system is studied under a healthy state and three damaged ones, each considering a non-evolving crack of 15, 30 and 45 cm length respectively. These damages were artificially induced by creating the smallest one and letting it evolve naturally. The detection attempt of three damages is achieved through a parametric method of Multiple Models using four and five sensors. The experiment took place under variable Environmental and Operational Conditions (EOCs), as a result the available measurements has a significant level of uncertainty and noise hindering the detection problem. Nevertheless, cracks of 30 and 45 cm length are successfully detected with high true positive rates over low false alarms.

Keywords

statistical time series method, simplified system SHM, damage detection, wind turbine blade, variable environmental and operating conditions

MOTION SIMULATION OF A CRANE BRIDGE IN AN INDUSTRIAL SPACE WITH STATIC OBSTACLES

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ABSTRACT

This thesis presents an application that simulates the movement of a crane bridge in an industrial area with static obstacles. Firstly, it recognizes the basic principles of the operation of lifting devices, records related applications of artificial intelligence, describes heuristic algorithms and investigates the field of motion simulation of lifting devices in general. It presents the problem of simulating the movement of a bridge crane, records the mathematical models, the various parameters, and the approach to the solution of the problem and the visualization of the motion of the mechanism. It also presents the approach to create the 3D environment, it simulates the structural elements of the lifting device, as well as the approach to develop a search algorithm that allows the crane bridge to avoid the static obstacles that exist in the industrial space. It also explains the structure and operation of the layout with relevant images and instructions. It develops and simulates three different operating scenarios with different obstacle layouts and presents relevant information. At the end of the thesis, some major conclusions are listed as well as future research perspectives.

Keywords

Simulation, Bridge crane, Industrial Area, Obstacles, Heyristic algorithm

FAULT DETECTION IN RAILWAY SUSPENSIONS UNDER VARIABLE CONDITIONS VIA MISO TRANSMITTANCE FUNCTIONS AND NEURAL NETWORKS

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ABSTRACT

The focus of this Diploma Thesis it the detection of minor faults in all railway vehicle's suspension component types under varying operational conditions. These conditions are the speed of the vehicle and the change in geometric profile of the railway tracks due to wear. Monitoring the health condition of suspension components in real time helps to increase the travel safety, but also to reduce the cost of maintenance and downtime of the vehicle, as this is maintained based on the actual condition of its components. Damage detections is based on the vibration signals retrieved from the vehicle using the Simpack simulation program and are being processed with the help of Matlab computing program to detect the presence of a fault. The measured vibration signals are modeled though representations of Multiple Input Single Output (MISO) Transmittance Function ARX, the output parameters of which are not affected by the change in the geometry of the rails due to wear. The characteristic vector of the parameters of this modeling is fed into a Neural Network, which with the right training is called to offer robust detection in terms of the changing speed of the vehicle. The Neural Network architecture used is simple and based on limited training signals. The detection is considered more effective using the Multiple Models method, which is applied for comparison reasons. The latter succeeds in detecting minor damages even with a percentage of 100% correct diagnoses for 0% false alarms, in relation to Neural Networks, which show a lower efficiency (75% correct diagnoses for 10% false alarms).

Keywords

Neural Networks, MISO Transmittance ARX, Multiple Models, Railway Vehicle's Suspension, Minor Fault Detection

DIVISION OF ENERGY, AERONAUTICS AND ENVIRONMENT (JUNE 2022)

A COMPUTATIONAL STUDY OF THE BLOOD FLOW IN THE LEFT ATRIUM OF PATIENTS WITH ATRIAL FIBRILLATION

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ABSTRACT

The main object of this Diploma Thesis is the computational study of blood flow in the left atrium of patients with Atrial Fibrillation. Atrial Fibrillation is the most frequent cardiac arrhythmia worldwide, since it affects 1 to 2% of the general population, while it is accompanied by high mortality rates. Like any other arrhythmia, Atrial Fibrillation refers to cases in which the electrical activity of the heart involves abnormalities, which are often not completely treated with neither medication nor surgery. A critical treatment method, minimally invasive, is catheter ablation which is simultaneously conducted with the procedure of electrophysiological mapping of the left atrium. The scope of this project is to create a framework for the comparison of mappings of multiple wall shear stress indices (which according to experiments are associated with the cardiac electrical activity) with electrophysiological mappings, using patient-specific data provided by doctors. Possible correlations can supply doctors with crucial information in a direction of improving the ablation process outcomes. Reconstruction techniques are implemented to convert two-dimensional MRI images into three-dimensional models of the left atrium. Following the optimization of the 3D model, the mesh generation and the solution of the cardiac flow procedures take place. Both of these processes are performed in the open-source software, OpenFOAM®, as we take advantage of the countless capabilities offered. After generating the mesh, a procedure of paramount importance for a computational study, the mesh independence study is carried out under steady state conditions using the simpleFoam solver, aiming to obtain the most suitable model for the present project. At the same time, various turbulence models and boundary conditions are tested in order to detect any possible differences in blood flow behavior. Finally, a transient flow simulation of a realistic cardiac cycle is conducted, utilizing the pisoFoam solver, since our main goal is to visualize the distribution of a variety of hemodynamic parameters, such as the Oscillatory Shear Index, as well as indices for indicating blood stasis in high-risk areas of the left atrium, like the Left Atrial Appendage.

Keywords

CFD, OpenFOAM, Wall Shear Stress, Atrial Fibrillation, Hemodynamics

NUMERICAL STUDY OF FLOW INDUCED NOISE AROUND A RIGID BODY

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ABSTRACT

In the present paper, an attempt has been made to use the rhoPimpleAdiabaticAcousticFoam solver for OpenFoam, to numerically predict the aerodynamically generated noise around an acoustically rigid body. The methodology employed by the solver is hybrid, so, firstly the flow field is solved and then the flow field solution is used to obtain the effective sound sources, which are used for the independent solution of the sound field, in this case, using Lighthill's analogy.

Two solid bodies were studied, in two dimensions, aerofoils and cylinders. Simulations were performed to evaluate the reliability of the flow solution for different geometry parameters and Reynolds numbers, and then the acoustic field was calculated and evaluated.

The study showed that the solver manages to yield promising results for the frequency of the acoustic field, as well as for the qualitative distribution of the produced noise and its qualitative change according to the changes in the geometry. However, further investigation is needed regarding the accurate prediction of the amplitude of the acoustic pressure. Finally, it was observed that the computational cost required to calculate the acoustic field is much higher than that required to calculate the flow field.

Keywords

OpenFoam, Acoustic Analogies, Airfoil, Cylinder, Aerodynamically generated noise

LARGE EDDY SIMULATIONS OF TURBULENT, STRATIFIED PROPANE-AIR FLAMES UNDER INLET PREHEAT USING THE FINITE RATE CHEMISTRY AND PARTIALLY STIRRED REACTOR CLOSURES

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ABSTRACT

Nowadays, there is a huge demand for more efficient and less polluting combustion systems. To achieve this, the academic community has turned to lean and super-lean fuel-air mixtures. With this in mind the study of flame stabilization around bluff bodies aims at better understanding combustion phenomena and reducing pollutants, through innovative combustion devices. Although, in these laboratory scale flames, the Reynolds numbers and pressure levels may not always be representative of technical systems bluff-body flame research results have contributed to the development of computational methods for general combustion problems.

The object of the present thesis is the simulation of a turbulent, stratified propane flame, which is stabilized on an axisymmetric disk baffle. The flame is stabilized on a recirculation zone located downstream of the bluff body. The turbulent flow field was modeled using the LES (Large Eddies Simulations) model and the propane combustion was solved by a general chemical mechanism with 22 species. Chemical kinetic was modeled on the Partially Stirred Reactor (PaSR) model, an approach that Fluent, Ansys's commercial package, incorporated in the latest version. The Partially Stirred Reactor model is believed to tackle turbulent combustion phenomena better than other existing models because its partially stirred assumption in the finer scales is more relevant to the nature of the problems studied here. Specifically, the model considers the existence of an ideal structure in which the phenomenon of chemical kinetics and turbulent flow field interact and co-exist. On the contrary, the Implicit LES model considers that chemical kinetic dominate in the ideal structure, ignoring the subgrid mixing by turbulence. The results obtained will be compared with simulations with the ILES model, for the approach of chemical kinetics, but also with experimental measurements of the velocity and temperature fields. The modeling attempts

to evaluate the chemical kinetics models PaSR and ILES. Simulations were solved with the software Fluent, Ansys's commercial package.

Keywords

Large Eddies Simulations (LES), Partially Stirred Reactor (PaSR), Propane Combustion, Stratified Turbulent Flame, Bluff Bodies

EXPERIMENTAL INVESTIGATION ON REACTION TO FIRE OF WOODEN BUILDING MATERIALS WITH A CONE CALORIMETER

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ABSTRACT

For the purpose of avoiding and preventing accidents as well as for the protection of human life and property, the industry is engaged in the continuous research, study and development of fire safety technology. Fire safety is ensured by a set of strict rules and specifications set by existing legislation. The use of appropriate materials in buildings plays a crucial role in the level of fire protection. Of the various cases of fires, that of fire coming from the burning of wood is a special case which can prove to be catastrophic.

The aim of this study is to investigate such a case of fire resulting from wood burning, based on the ISO-5660 standard, focusing on fire response efficiency, flame spread rate, ignition time as well as heat release and production of smoke. These properties have been measured by a small scale fire test method the cone calorimeter and are presented for different types of wood. Test data is also used to obtain information about the material response to fire and to help categorize specimens. Taking into account all the data, the results are presented, giving an overall picture of the issue of fire safety and the use of wood as a building material in case of fire.

Keywords

Fire, Fire Safety, Wood, Fire Response, Cone Calorimeter

ENERGY AND ENVIROMENTAL APPLICATIONS OF AN INTENSIVE GREEN ROOF SYSTEM

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ABSTRACT

One of the most popular and well documented nature-based solutions to improve urban sustainability, to reduce energy consumption and to mitigate urban heat island effect is the engineering system of Green Roofs. Green roofs, (GR), are designed as engineering applications with main objective to create an artificial ecosystem attempting to improve the necessary balance between biotic and a-biotic components in the built environment. GR systems present a significant number of benefits, extensively described in the scientific literature, which could be summarised as follows:

1. Energy benefits: they are described and expressed through building's energy consumption reduction especially for cooling and indoor air temperature decrease

2. Environmental benefits: GR could improve carbon sequestration through photosynthesis and through energy consumption reduction because of evapotranspiration as well as are able to contribute to air pollutants minimization through deposition

The present Diploma Thesis includes in the first chapter a literature review of the main GR system models describing the thermal performance of the system using different scientific approaches as well as of the main system's energy and environmental benefits. In the second chapter an extensive development of several case studies is presented and analysed consisting of a simple non-insulated roof, non-insulated roof with three different types of green roofs, an insulated roof, and the insulated roof with the three GR systems. Extensive calculations of the systems thermal transmittance coefficient were carried out and presented and results were compared with theoretical and accurate ones, and they were found of close agreement.

Keywords

Green roof, thermal transmittance coefficient, U -values, urban heat island effect, planted roof, thermal insulation

OPTIMIZATION OF THERMAL EFFICIENCY OF PASSIVE SOLAR SYSTEM (TROMBE WALL) BY INCORPORATING PHASE CHANGE MATERIALS

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ABSTRACT

The subject of the present diploma thesis is to investigate the effect of a flat tile type vortex generator with hole in the flow and thermal field of a heated rectangular tube from which air passes. The investigation of the effect of the tile is made for different hole diameter values, angles of attack and Reynolds numbers of air at inlet. The aim of the study is to enhance the heat transfer, while achieving the lower possible pressure drop.

The computational analysis has been completed entirely by using Ansys-Fluent program. The procedure was followed consisted of the design of the geometries of the problem, the creation of their meshes, the adjustment of the parameters and the determination of the boundary conditions, leading to the final solution. The viscous model used is k-ε Realizable, with the energy model was activated. The simulations were performed for a constant temperature on the inner surfaces of the tube equal to 650 Kelvin and for air temperature at inlet 273 Kelvin. At first, the different hole diameter values (0,2,4,6,8 mm) were investigated. The optimal diameter was selected, examined and compared with an empty tube of the same dimensions for different Reynolds numbers of air at inlet (5,10,15,20,25 k). Consequently, the tile with the optimal diameter chosen it was investigated to the different angles of attack (0,25,45,65,80 degrees). Then the results were exported and compared and the tile with the angle presented the best results was picked. Following, the tile that picked previously investigated and compared with and empty tube of the same dimensions for different Reynolds numbers of air at inlet (5,10,15,20,25 k). For each simulation performed, the average temperature at the outlet of the tube, the average Nusselt number and the Darcy friction factor (pressure drop coefficient) were calculated and the diagrams of the above quantities were constructed as a function of each parameter.

Finally, the conclusions that emerged from the results of the computational analysis were analyzed and some ideas were suggested for further research.

Keywords

Ansys-Fluent, Vortex Generator, Heat transfer, Pressure Drop, Reynolds

NUMERICAL SIMULATION OF FIRE IN A LIBRARY

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ABSTRACT

Fire is a phenomenon that occurs in various forms, but all involve chemical reactions between flammable materials and oxygen. When properly harnessed it is very beneficial, as it can be used as a source of energy for industrial and domestic needs. But when it gets out of control it can cause loss of life and major property damage.

In this thesis we have dealt with the second case and more specifically with building fire. More specifically, a computational simulation of fire evolution in a building was carried out with the help of a computational fluid dynamics software. The study building is a university library with external thermal insulation and the software used is called FDS (Fire Dynamics Simulator) and is based on the Large Eddy Simulation model for solving the differential equations related to fire.

At first, a reference was made to the characteristics of fire in a building, the factors that influence its development, the way it affects it as well as the behaviour of smoke. Then, various information concerning the FDS code as well as the models used in it were given. Also, the equations used and solved by the software to achieve the simulation were analysed. In the third section of the paper, a fire in a typical room was simulated and the resulting data were compared with an experiment available on the internet.

Finally, a simulation was performed in a real building, which as mentioned above is a library and the conclusions drawn from the thesis regarding the simulations were presented.

Keywords

Fire Simulation, Computational Fluid Dynamics, FDS Software, Comparison of Results, ETICS (External Thermal Insulation Composite System)

COMPUTATIONAL INVESTIGATION OF THE EFFECT OF A VORTEX GENERATOR OF LONGITUDINAL FLAT PLATE TYPE, ON THE FLOW AND THE THERMAL FLOWFIELD OF A PIPE OF RECTANGULAR CROSS-SECTION AND CONSTANT TEMPERATURE OF WALLS, FOR DIFFERENT INCLINE VALUES AS TO THE CROSS-SECTION PLANE, IN TURBULENT FLOW

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ABSTRACT

The work presented focuses on the modeling and study of a gas flow inside a rectangular tube, aiming to achieve maximum possible heat transfer. Specifically, the walls of the pipeline under study are at a constant temperature thus transferring heat to the fluid. At the same time, a special ramp was designed and added to optimize the process, aiming to create a turbulent flow field. The ramp was placed along the pipeline and stabilized at its upper and lower sides and its effect on the flow was studied for different angles in relation to the x-axis. Specifically, the angles studied were 20˚, 30˚, 45˚, 60˚, 75˚ and 90˚. The ramp's geometry is rectangular and it is made of the same material as the tube, which means that, in addition to creating turbulence, the ramp also contributes to the heating of the fluid.

Flow modeling and analysis was performed using the Ansys Fluent computational program. Initially, the design packages offered by the program were used for the design of the models. This was followed by the meshing of the model and the resolution of the problem. During the flow modeling, great care was taken to create a reliable model that would correspond to reality. Important elements of the modeling were the diligent discretization, but also the correct choice of parameters based on the needs of the problem. The viscous model selected as the most suitable for the flow study is k - epsilon. Finally, the results obtained from each model were processed to select the best possible layout. The most basic criterion is the change in temperature of the volume of the fluid which enters the pipe at initially low temperature and its optimal heating is required. It is worth noting that the modeling was done with air flowing in the pipeline, however, this device can also be applied to gas pipelines.

Keywords

Tube/Pipeline, Ramp, Temperature, Heat transfer, Computational flow analysis, Vortex generators

INSTALLATION STUDY FOR A 500 kW PHOTOVOLTAIC POWER UNIT ON FIXED AND SUN TRACKING BASES

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ABSTRACT

The conversion of solar energy into electricity through photovoltaics (PV) has become quite popular in recent decades, due to the possibility of switching from fossil fuels to renewable energy sources. More specifically, advances in photovoltaic technology and the financial sector have made it possible to reduce the cost of solar cell energy to the energy cost of conventional fossil fuels. Thus, photovoltaics already plays an important role in addressing the biggest challenges of our planet, such as global warming, climate change, and air pollution. In this dissertation, the output of a 500-kW photovoltaic unit was studied in the case where we have fixed or sun tracking bases. Initially, reference is made to the photovoltaic phenomenon as well as to the categories of photovoltaic systems available. Reference is made to the way of supporting the photovoltaic (PV) panels, and the two ways of their placement are explained. The sections that make up a photovoltaic park, convert the solar energy into electricity and distribute it to the PPC network, are identified. A specific area is selected in the Greek territory and with the use of the PVsyst program the efficiency of the photovoltaic park is calculated, in the cases that the PV panels have been placed on fixed or mobile bases respectively. Finally, the results obtained from this study are presented, along with the differences that are observed in the performance of the photovoltaic panels, as well as the differences that exist in the installation costs.

Keywords

Conversion efficiency, photovoltaic power unit, fixed bases, mobile bases, PVsyst

COMPUTATIONAL INVESTIGATION OF THE FLOW AND THERMAL FIELD OF A HELICAL TUBE OF ONE TURN FOR THREE DIFFERENT VALUES OF THE CURVATURE RATIO Γ AND FOR CONSTANT WALL TEMPERATURE

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ABSTRACT

This work aims at the computational investigation of the transition from laminar to turbulent flow of a helical (curved) tube with constant curvature ratio, as well as at the tube's thermal analysis. As far as the flow's transition is concerned, most important task is the definition of the Reynolds number critical value, which differs from that of a straight pipe. Also, the study of in which manner this value varies with the position along the tube and its curvature ratio is of great interest. This is achieved by applying four criteria of transition from laminar to turbulent flow. As far as the thermal analysis is concerned, it aims at the comparison of the heat transfer between the helical tubes and their conventional counterparts of straight tubes, with same diameter and length. In any case, for the calculation of the results in the helical tube, the development of the secondary flow of the first kind must not be ignored, for it affects the main flow significantly.

Calculations on three helical tubes (geometries) were conducted, in order to define the range of critical Reynolds number, each one with different curvature ratio: for $\gamma = 0.1$, $\gamma = 0.05$, $\gamma = 0.025$. The computational analysis was conducted with ANSYS|FLUENT, applying three different CFD model setups for each geometry. Four criteria for transition from laminar to turbulent were used. Each one employs a different metric 1) the axial pressure-gradient dP/dx, 2) the turbulent viscosity μ_t, 3) the wall shear stress τ_w, and 4) the intermittency factor, a quantity that indicates the probability that a point of the working fluid is in turbulent flow. Based on the results of these quantities, mathematical relations for the calculation of the Re_{crit} range are formed, as the transition of the flow inside a helical tube, as well as in a straight one, does not occur immediately, but gradually. In fact, transition in helical tube appears to happen smoother, in a greater range of critical Reynolds number than that of the straight tube.

For the thermal analysis of the helical tubes, outlet temperature was calculated and compared to that of straight tubes. For the accurate comparison, the straight tubes were designed of equal diameter and length to that of the helical tubes, as well as, they performed under the same meshing, model setups and boundary conditions. For better monitoring of thermal differences between the helical and straight tubes, temperature along the geometries was also calculated and compared.

Keywords

Curved helical tube, Transition, Critical Reynolds number range, Secondary flow of the first kind, Computational Fluid Dynamics

EXPERIMENTS IN A CONE CALOMETER

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ABSTRACT

This diploma thesis deals with the combustion of different gases in a Cone Calorimeter. More specifically, experiments are performed with three gases in order to observe their behavior and to record the amount of heat released during their combustion. Finally, the estimated heat of combustion results are compared with values from the literature. This thesis consists of 6 main chapters.

The first chapter describes the objective of this diploma thesis and presents an introduction both to the phenomenon of combustion and to the Cone Calorimeter, as it is used in the experiments that took place for that thesis.

In the second chapter, the three gases that were used in the lab for the experimental work, are presented in detail.

The third chapter deals with calorimetry and introduces in detail the most influencial and most commonly used calorimeters, and of course the cone calorimeter is also described.

The fourth chapter describes the experimental setup and the steps for the calibration of the instrument used for the implementation of the experiments in the laboratory of the Department of Mechanical Engineering and Aeronautics, at the University of Patras.

The fifth chapter presents the experiments and the results for each gas and for the different flow rates used. The quantities studied, of interest in this present work are: the Heat Release Rate (HRR), the Total Heat Release Rate (THR), the Carbon Monoxide Production Rate (CO) and the Carbon Dioxide Production Rate (CO2). Combined diagrams of the above variables for all the mass flow rates tested are also presented.

Finally, in the sixth chapter all the results are compared with the existing literature and suggestions for following work are advanced.

Keywords

Combustion, Cone Calorimeter, Heat Release Rate, Heat of Combustion

COMPUTATIONAL STUDY OF THE EFFECT ON THE FLOW AND THERMAL FIELD IN A TUBE OF RECTANGULAR WITH THREE CIRCULAR HOLES FOR DIFFERENT VALUES OF HOLE DIAMETERS AND ANGLE OF ATTACK OF THE TILE

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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 three circular holes in the flow and thermal field of a heated tube with rectangular cross-section. The aim of this study is to enhance the heat transfer inside the tube, while achieving the lower possible pressure drop. In order to achieve this, many computational simulations took place, each time with different hole diameter values, Reynolds number at the inlet and angles of attack for the tile.

To begin with, the basic concept of fluid mechanics is described, such as the different types of flow, the analysis of the boundary layer, the heat transfer mechanisms and the theory regarding Vortex Generators and how they contribute to the heat transfer inside the tube. Also, an introduction is being made for CFD through the ANSYS-FLUENT program which is used for the computational simulations.

After that, the geometries of our problem and suitable grid for them were designed. Then the appropriate parameters and conditions of the simulations were adjusted.

At first, the different hole diameter values of the tile were investigated (D=0,2,4,6 mm), where the optimal diameter was selected according to some desired quantities (average outlet temperature, average Nusselt number, pressure drop coefficient).Then, a comparison was made between an empty tube of the same dimensions and a tube where the tile has holes of the optimum diameter, for different Reynolds numbers at the inlet (5000,10000,15000,20000). This was followed by an investigation for the tile with the optimal hole diameter in terms of its different angles of attack (0,30,45,60,80 degrees), in

order to find the one that showcase the best results regarding the previous mentioned quantities. The desired angle of attack was then compared with an empty tube of the same dimensions for different values of the Reynolds number at the inlet (5000,10000,15000,20000). For each simulation the appropriate diagrams were constructed to better understand and showcase the results.

In the end, the conclusions that emerged from the investigation were explained and some suggestions were made for further research.

Keywords

Vortex Generator, Heat transfer, Pressure Drop, Nusselt Number, Reynolds Number

EXPERIMENTAL INVESTIGATION OF THE FLOW AND MIXING FIELD CHARACTERISTICS DOWNSTREAM A NOVEL CONFIGURATION, SUITABLE FOR THE AERODYNAMIC STABILIZATION OF STRATIFIED GASEOUS FLAMES

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ABSTRACT

In the present Diploma Thesis, the theoretical background, the measuring devices as well as the laboratory experimental setup used for the study of the flow and mixing field characteristics in a coaxial flow device that can stabilize aerodynamically stratified gas mixtures are presented. Apart from the above, the results obtained with the experimental devices and their analysis are presented. The employed experimental configuration was designed and developed in the Laboratory of Applied Thermodynamics. First, the main and necessary theory of the disciplines on which the subject of partial premixing of mixtures is based is presented. Moreover, a literature review of relevant works on coaxial flows, in cylindrical duct arrangements, aiming in the creation and control of the developing recirculation zone is presented. This is followed by a detailed and extensive presentation of the laboratory experimental instrumentation used, along with their involved uncertainty sources. The laboratory experimental setup used is then presented, following the basic theory and rationale which resulted in the creation and development of the investigated setup. Subsequently the results obtained by the infrared spectroscopy method using Fourier transform are presented. These results relate to the case in which fuel (propane) is used in the setup and conclusions are drawn on how the injection height and fuel supply affects the partial premixing. Finally, the results obtained (no-fuel) for the representation of the flow field with the PIV (Particle Image Velocimetry) method are presented. From these results it can be concluded whether the installation has the potential for recirculation to occur at a distance downstream of the outlet level and at which velocity ratio between the two air streams.

Keywords

Mixture stratification, Flow recirculation, Combustion, Mixtures, Coaxial Flows

APPLICATION OF NUMERICAL ANALYSIS TECHNIQUES FOR THE SOLUTION OF THE STREAM FUNCTION AND DEVELOPMENT OF SIMPLE COMPUTATIONAL CODES FOR THE FLOW VISUALISATION OF THE FLOW FIELDS

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ABSTRACT

In this dissertation, computational and theoretical study of fluid mechanics was performed. In the first chapter an introduction was made to the equations describing the fluid flow. Complete proofs are given for the equations of energy, momentum and the equation of continuity in conservative and non-conservative form. There is also an analysis of the importance of boundary conditions and the categorization of partial differential equations according to the physical phenomena they describe.

In the second chapter, the finite difference methods and the finite volume method were analyzed. Emphasis was placed on the description of irrotational, incompressible and inviscid flow which is described by the Laplace equation.

In the third chapter computational simulations are done. Various programs have been developed in the Python programming language to simulate the flow of irrotational, incompressible inviscid fluid flow. The first application was made based on the boundary conditions of the problem that was solved analytically in the previous chapter and the results were very satisfactory. Then flows of famous experiments in non-orthogonal geometries simulated and the results are very satisfactory. Large lattice mesh grids were created with rectangular rectangles in various orientations and sizes to be inserted into the flow. The flow had the expected results, which were compared with known experiments. Then the flow between 2 parallelograms was studied by the computer simulations. In each computer application the shapes had different sizes and distances from each other. In the last application, the flow between 4 and 5 squares in different arrangements was studied. Based on the previous simulations and the results we can know that the simulations in street canyons are correct.

Finally, in the fifth chapter we study the flow of pollutants through street canyons. This study was based on “CFD MODELLING OF AIR POLLUTION MOTION INSIDE A BUILDING BLOCK”, which was published by members of fluids mechanics laboratory, Mechanical Engineering and Aeronautics, University of Patras. In this analysis we studied, the flow of CO_2, CH_4, NO_2 pollutants for different speeds was studied, using the commercial package Fluent.

Keywords

Computational Fluid Dynamics, Pollutants flow, Numerical Methods, Finite difference method, Laplace equation

USE OF HYBRID PHOTOVOLTAIC/THERMAL COLLECTORS (PV/T) FOR ENERGY SAVING IN GREENHOUSES

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ABSTRACT

The purpose of this thesis is to assess the energy savings resulting in a greenhouse structure, following the addition of hybrid photovoltaic (PV/T) systems as well as limiting the maximum growing temperature within its interior, using shading covering. In the first chapter, there will be a reference to photovoltaic systems as well as the evolution they have received over the years, the photovoltaic phenomenon as well as to the EU policy on renewable energy systems (RES) in general, while it finalizes with reference to hybrid photovoltaic systems (PV/T). Subsequently, in the second chapter, there is an extensive bibliographic review for non -conventional greenhouse heating systems (heating using photovoltaic, solar panels, PV/T devices), as well as PV efficiency studies for use in greenhouses. Consequently, there is a bibliographic review in ways of cooling of the greenhouse unit can be achieved and the efficiency of each application. Specifically, cooling through ventilation, wet sidewalks combined with dynamic ventilation, hydro-phosis systems as well as the shading, covering and whitening method, are analyzed. In the third chapter, the recent technologies found in greenhouses are briefly analyzed. In the fourth chapter, the installation used to prepare the study is extensively analyzed. In particular, reference is made to the factors affecting greenhouses, as well as the choice of the plant for the study and the appropriate conditions required for its growth. Following, is the description of the installation, as well as any optimization it has accepted. Then, there is a theoretical evaluation of the PV/T system as well as the expected theoretical consumption of the two identical greenhouses (with or without PV/T) for May, while further ways to maximize energy savings are investigated. In the fifth chapter, follows the evaluation of theoretical measurements compared to the ones measured, as well as the energy savings of heating resulting from the use of the PV/T system. Finally, on the typical day of May a shading net was installed, with a shading factor of 80%, and the temperature drop that could offer, in combination with or without the use of ventilation, was observed.

Keywords

greenhouses, photovoltaic heat collector, PV/T system, theoretical consumption, energy saving

COMPUTATIONAL STUDY OF AERODYNAMIC PERFORMANCE OF WIND TURBINE BLADES MADE FROM VARIOUS AIRFOILS

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ABSTRACT

The subject of this thesis is the computational investigation of the aerodynamic performance of wind turbine rotors in order to estimate the aerodynamic power coefficient of a three-bladed horizontal axis wind turbine. The computational fluid dynamics software ANSYS Fluent and the QBlade software for blade design were used to carry out the work.

Initially, the selection of airfoils for the design of the blades is performed. For this research, the NACA 4412 and NACA 63-415 airfoils are selected. Then, the blade design is done using the QBlade software, for a blade length of 50m and a tip speed ratio equal to 7. The two geometries are then imported into ANSYS Fluent software, where a computational study of single-phase airflow around the blades for fluid velocities of 10m/s, 12m/s and 15m/s is performed. Two different turbulence models, Generalized k-ω (GEKO) and SST k-ω, are used for the computational study in order to find the most suitable one. The distributions of pressure, velocity and shear stresses on the blades, the wake of each blade, the power coefficient Cp as well as the stagnation, maximum velocity, separation, and reattachment points of the boundary layer are calculated.

The results show that the power coefficient Cp for both blades increases slightly with increasing fluid inlet velocity, and the power coefficient of NACA 4412 is higher than that of NACA 63-415 for both turbulence models. The wake is observed to decrease with increasing fluid inlet velocity and with distance from the blade, while the NACA 63-415 blade is observed to produce slightly more wake for all fluid inlet velocities than the NACA 4412. Finally, no boundary layer separation occurs in any simulation.

Keywords

aerodynamic performance, computational fluid dynamics, blade design, horizontal axis wind turbine, wake behavior.

DIVISION OF MANAGEMENT AND ORGANIZATION STUDIES (JUNE 2022)

QUALITY ASSURANCE SYSTEM ANALYSIS FOR THE "OPEN-MIND GROUP LTD" COMPANY

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ABSTRACT

The aim of this diploma thesis is to capture the quality management system applied in the company Open Mind Group Ltd. The first chapter presents general data that define the quality management system, as well as some historical data and general principles regarding the standard of ELOT ISO 9001: 2008 which is the subject of this diploma thesis. The second chapter presents the company Open Mind Group Ltd. It describes its scope of work, its human resources, as well as some financial data. In the third chapter, the quality management system is analyzed according to the ELOT ISO 9001: 2008 standard. In the fourth chapter, some elements from the application of this system are described, in the company Open Mind Group Ltd. Finally, the necessary conclusions are drawn from the diploma thesis.

Keywords

Quality management, ISO 9001:2008.

EXPLAINABLE GRAPH BASED RECOMMENDATION SYSTEM WITH THE UTILIZATION OF GRAPH NEURAL NETWORKS

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ABSTRACT

The present thesis investigates the utilization of graph neural networks in order to create an explainable, content-based recommendation system. The recent growth in technology and the constantly increasing interaction with computers have enabled an imperative need for data collection from users' reviews. As a result, in the light of improving user experience it is deemed necessary to leverage the data identified within the reviews. Providing recommendations tailored to the individual heavily relies on efficient natural language processing and link prediction among the various information gathered from users. Within the scope of the present thesis, the link prediction problem is approached through the lens of artificial intelligence and machine learning. In specific, a magazine review database is considered as an input to a heterogenous graph, and two link prediction algorithms are used to determine the relation among the different entities. In addition, the two models are trained, and a comparative study is conducted based on prediction accuracy, aiming at identifying the most efficient solution.

Keywords

Recommendation system, graph, neural network, review, link prediction

DEVELOPMENT OF PERFORMANCE INDEX FOR THE EVALUATION OF TH ENVIRONMENTAL BEHAVIOUR OF SUPPLIERS

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ABSTRACT

In recent years, the industry has focused on accessing environmental impact, as it is likely to result from companies' operation and productive activities. Industrial companies are changing their environmental behaviour, and are turning to a "green policy" due to the need for a rational management of raw materials, products and waste. The Greek industry, following environmental legislations, focuses on an awareness-raising approach, and implements actions to create a protection grid, due to the effects of climate change, but also the rising of energy costs.

The primary aim of this graduate thesis is to understand and investigate the effort and behavior of companies, operating in the Greek industry market, regarding the culture of environmental evaluation of their suppliers. To this end, a quantitative survey was conducted with a questionnaire on a number of 80 companies active in the following sectors: pharmaceutics, fish farming / aquaculture, construction materials, food industry, and recycling - solid waste management.

During the analysis of the results, it is found that the general picture of the environmental behavior of companies in sectors of Greek industry is satisfactory. Overall, all companies in the present survey maintain a positive attitude towards green supplying, regardless of the industry in which they operate. Nevertheless, companies in the sector of building materials express a more neutral attitude regarding the environmental evaluation of suppliers as a parameter for their final cooperation. Almost all companies strive to strengthen a healthy green supply chain; this finding demonstrates the willingness of companies to work with suppliers that operate on the basis of environmental commitments. On the other hand, companies in the industrial sector maintain a neutral attitude towards the imposition of boycott on their suppliers, who act as environmental offenders. It seems that the Greek industry is focused on meeting the environmental criteria, showing willingness and respect, however there is room for full integration of environmental culture in all their functions.

Keywords

Evaluation, Environmental Behaviour, Suppliers, Environmental Management, Supply Chain

DIVISION OF APPLIED MECHANICS, TECHNOLOGY OF MATERIALS AND BIOMECHANICS (SEPTEMBER 2022)

THE CONTRIBUTION OF SHOT BLASTING TO THE CORROSION

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ABSTRACT

It is commonly known, the phenomenon of corrosion is a major issue in the performance of reinforced concrete structures, as it significantly affects their mechanical performance and thus their lifetime. Therefore, a proposal to strengthen the resistance of concrete reinforcement steel against corrosion is considered particularly interesting and relevant over time.

For these reasons, in this project, the shot blasting process is proposed, as a method of enhancing the mechanical performance and anti-corrosion behavior of the steel reinforcement. For this, accelerated salt spray corrosion experiments were carried out on reference specimens and shot blasted (olivine and glass beads) reinforcing steel specimens for various exposure times according to the ASTM B117-94 standard. Part of these samples was encased in the concrete before being exposed to the corrosive environment.

Upon completion of each exposure time, cleaning was performed (ASTM G1), and for the characterization of corrosion damage of reinforcing steel (B500c) was use optical microscope. Also, in order to determine the mechanical properties of gradually corroded samples part of these was subjected to tensile tests. The results showed that the shot blasted specimens demonstrated higher resistance to corrosion than the reference specimens both in the case of "bare" and "encased" samples. In other words, they developed a lower degree of corrosion damage and specifically lower mass loss rates and smaller pitting depths. A fact that was also reflected in the results of the mechanical tensile tests of the shot blasted specimens.

Keywords

Steel, Concrete, Corrosion, Salt spray method, Shot blasting process, Mechanical properties

INTERVAL-BASED COMPUTATION OF THE UNCERTAINTY IN THE MECHANICAL PROPERTIES AND THE FAILURE ANALYSIS OF UD COMPOSITE MATERIALS

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ABSTRACT

An interval-based method is presented to evaluate the uncertainty in the computed mechanical properties and the failure assessment of composite AS4-35016 unidirectional (UD) laminate. The mechanical properties of the UD lamina were derived using simplified micromechanical equations. The input mechanical properties of the constituents was real values from experiments with uncertainty level that reaches the value of 15%. The intervals of the mechanical properties of the composite material were computed with Intlab, a Matlab's toolbox, but the complete procedure of computing the range through global optimization using C++, is discussed in Chapter 5. Interval arithmetic operations were used to evaluate the uncertainty in the Puck's failure criteria in a closed form. Using the closed-form uncertainties of intervals and sets of stresses obtained by finite element analysis, the uncertainty in the failure assessment was quantified for the composite laminate. From the uncertainty of the input mechanical properties with the highest to reach the level of 15%, the computed uncertainty for the mechanical properties ranges from 6.99% to 21.68%. For evaluating the uncertainty effect on the efficiency of failure criteria, a probability of failure function, which employs interval boundaries, was defined and proved capable of evaluating the whole spectrum of stresses.

Keywords

unidirectional composites; interval analysis; micromechanical analysis; failure analysis; mechanical properties; uncertainty level

HIGH-FIDELITY NUMERICAL STUDY ON THE EFFECT OF RIBLETS ON THE AERODYNAMIC PERFORMANCE OF THE FLAT PLATES

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ABSTRACT

In this student research project, the methods of aerodynamic improvement of a wide variety of aircrafts, with the main objective of reducing drag force, are examined. Different ways of drag reduction are analyzed but an in-depth and further study is made on the methodology of riblet films.

Firstly, we find the literature and references from experts in the subject, as to the positive impact of riblet films in terms of drag reduction. As we firstly do our research of the riblet films, then the different geometries of riblets are studied, experimental and theoretical results under specific conditions are reported. Also, their installation in the aviation industry and various problems faced by scientists who are called upon to carry out the proper use of riblets are mentioned.

Then the results of the ONERA M6 wing are validated so that we have a first attempt with the computational fluid dynamics programs. Three different meshes were created in terms of their density, but of the same type, in order to compare the numerical results with the experimental ones. From the validation of the wing results we have drawn some useful conclusions for the correct creation of the meshes, which will then be used for the study of riblets.

Subsequently, five different models of riblets on a flat plate are examined, which are placed inside a rectangular duct of fixed dimensions and located on its lower surface. The rectangular duct was chosen because the top surface is a flat surface parallel to the flow as is the bottom surface of the duct, which is the riblets, so a simultaneous comparison of the two surfaces can be made without the need for additional grids.

The models were tested under the same conditions and for the dimensioning of the riblets some parameters were taken from the flight conditions of the Greek Civil Unmanned Aircraft

RX-1, HCUAV. In addition, four different speeds were used for each model. From the results we can have a general view of the ideal non-dimensional distance of the riblets s+, as well as the variation of the vortices, created due to the flow, due to the riblets. We also notice a change in the flow velocity along the riblets.

Keywords

RIBLETS, UNMANNED AERIAL VECHILE, DRAG REDUCTION, WING, AERODYNAMIC ANALYSIS

ANALYTICAL, EXPERIMENTAL AND NUMERICAL COMPARISON OF COMPLIANCE IN BONDED JOINTS UNDER MODE I FRACTURE MECHANICS EXPERIMENTS

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ABSTRACT

In the present work, the mechanical behavior of an interfacially cracked layered beam or an adhesive joint with a crack at the interface is investigated, with the possibility of the presence of the bending-extension coupling and residual hygrothermal stresses. The mechanical analysis of this model is presented in detail, through a generalized adhesive joint (symmetric and non-symmetrical), based on the Timoshenko beam theory and the deformation models, rigid and semi-rigid joint models. The kinematic equations of the adhesive joint for the two models are presented. Then, the specific case of the mode I double-cantilever beam test is examined, from which the compliance and, through the Irwin-Kies relation, the energy release rate are derived analytically. Subsequently, with the help of a finite element method, for three representative adhesive joints, the UD//UD, UD//CP and UD//MD, the results from the analytical solution are validated for the compliance and SERR. In addition, the experimental data, force-displacement-crack length of a DCB test on a UD//UD joint are obtained, resulting in the experimental determination of the compliance and SERR. Therefore, a comparison of the results from the analytical and numerical methods, with the experimental results is made for the compliance and SERR. Finally, the conclusions of the analyzed methods are presented.

Keywords

Compliance, strain energy release rate, rigid joint model, residual hygrothermal stresses, double cantilever beam test

DESIGN, ANALYSIS AND OPTIMIZATION OF 3D PRINTED LATTICE STRUCTURES FOR ENERGY ABSORPTION FOR QUASI-STATIC COMPRESSION LOADING

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ABSTRACT

Cellular structures, such as lattices and honeycombs, have proved to be satisfactory for their applicability due to their outstanding properties, such as high strength, absorbed energy, lightweight design, and reduced vibration, which have been extensively studied and concerned. Because of their excellent properties, cellular structures have been widely used in aviation, aerospace, bioengineering, automation, sport, and other industrial fields. Nowadays, with the development of Additive Manufacturing (AM) technology this concept can easily be exploited and change the conventional material world, as it offers a design freedom so that complex geometries with the desired mechanical properties can be manufactured. Honeycombs are well-known for their out-of-plane energy absorption capacity, but in some applications, crushing occurs along any direction of the honeycomb. Therefore, it is important to enhance their in-plane behavior and techniques like foam filling and variation of the density through the structure are lately investigated. After a comprehensive literature review, we concluded that the performance of Nylon12 honeycombs have not been broadly explored, although it is a very promising lightweight material which can be used to 3D printing the structure. Thus, in this thesis we aim to investigate the performance of a Nylon 12 hexagonal honeycomb. A verification of the finite element (FE) model is conducted by comparing the results with published experimental work. The influence of the honeycomb's size on its performance was, also, studied. In consequence, to enhance the energy absorption (EA) of the Nylon12 hexagonal honeycomb the density of the structure is distributed, by changing the thickness of each cell wall, while the overall density remained equal to the initial uniform structure. Specific gradients led to the higher densification strain, increased specific energy absorption (SEA) and lower initial loads, while others to the opposite. Moreover, the honeycomb was filled with Rohacell foam of different densities, and it was found that the SEA increase up to 150%, while the density only a small portion 41%, but the initial loads increased, too. Finally, a structure which combine the aforementioned techniques is modeled and the results showed the highest increase of the SEA compared to the other two methods accompanied with lower initial loads. The FE models of all the three techniques were parameterized with a MATLAB code and the results were processed saved for future use.

Keywords

Additive Manufacturing, Cellular Material, Energy Absorption, Density Graded Structures, Honeycombs, Foam-filled structures

DESIGN, ANALYSIS AND WEIGHT OPTIMIZATION OF A UAV WING

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ABSTRACT

This thesis is a study for the design and optimization of a small wing, which will satisfy specific requirements for the mission of an unmanned aerial vehicle. In the design process, the determination of the initial individual values of the construction weight of the air vehicle was carried out by an iterative procedure and the accurate calculation of the wing loading and power loading, W/S and W/P respectively, parameters of the vehicle were estimated by a geometric method through a summary diagram to simultaneously satisfy all mission requirements. The initial estimates in the wing design were validated and redefined in the detailed design phase. This step formed the basis of aerodynamic analyses using the Finite Element Method (FEM) in ANSYS FLUENT software. The model with the initial approximation of the position and dimensions of the internal and external structures of the wing was designed in CATIA V5. At this point it was necessary to investigate methods of coupling the aerodynamic analyses and structural results through the interaction of the aerodynamic analysis solutions and its application on the wing surface (one-way Fluid Structure Interaction FSI analysis) to simulate the loads stressing the vehicle in flight and investigate its structural stability under real conditions rather than simplified non-continuous loading. In the experimental configuration of the wing, its structural response was studied with both aluminum alloys and composite materials. The application of composite materials was necessary to minimize the structure weight and a reduction of up to 50% was achieved. However further optimization of the structure led to the parameterization process of all wing parts and then the application of optimization algorithms through coupling them with the results of the FEM model. Optimal values for the position and thickness of the internal structures (ribs, spars, skin) were determined and a reduction of the structure weight from the initial wing configuration to the parametric design phase of up to 60% was achieved.

Keywords

UAV wing, Conceptual Design, ANSYS FLUENT, CATIA V5, one-way FSI methods, optimization algorithms.

DEVELOPMENT OF A DIGITAL TWIN TO SIMULATE THE POST-BUCKLING BEHAVIOR OF COMPOSITE STIFFENED PANELS

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ABSTRACT

The present work is dedicated to the development of a Digital Twin (DT) of a multi-stringer composite panel subjected to Quasi-Static (QS) loading. Four tests are executed with a maximum load of 250, 275 and 300 *kN*. At 250 *kN* two tests are carried out, one with the specimen being in pristine state (Before Impact – BI), and one where damage After Impact (AI) is present. The rest two tests involve only the specimen in the damaged state. During all four tests strain measurements are recorded via Fiber-Optic Sensors (FOS) placed on the specimen, while for the BI test the post-buckling behavior is captured via Digital Image Correlation (DIC). The purpose of the DT is a) to simulate the post-buckling behavior of the structure, and b) to be used as the healthy state baseline of a Structural Health Monitoring (SHM) system. Firstly, a Finite Element Model (FEM) of the panel is developed and Non-Linear Buckling (NLB) analyses are run via both implicit and explicit solvers. The implicit analysis simulates accurately the buckling load but appears too stiff in the post-buckling region. On the other hand, the post-buckling behavior of the explicit analysis is validated by the DIC findings, though at several load regions the FEM overestimates the acting loads. Then, Surrogate Models (SMs) are trained upon the FEM results (strains) to provide pristine strains for the SHM system. The trained SMs accurately replicate the FEM with presenting low RMSEs. Lastly, the SHM methodology is applied where, at start, a load identification process is executed utilizing the measured strains. The surrogate and experimental strain distributions are compared at multiple loads to examine if the induced damage can be detected and localized. The results show a successful detection and a semi-successful localization, as only the location of one impact is found. In order to have a more automated system, a Health Indicator (HI) is defined, and a healthy state threshold is specified. Via this method, the damage detection is achieved for both impacts, however only one of them is localized.

Keywords

Composite Stiffened Panels, Digital Twin, Surrogate Modeling, Structural Health Monitoring, Fiber-Optic Sensors

DESIGN, ANALYSIS AND OPTIMIZATION OF A 6U CUBESAT USING COMPOSITE MATERIALS

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ABSTRACT

Two of the most fundamental issues that have preoccupied humanity for many centuries and will continue to concern it, given the continuation of technological development, are both the creation and the end of the universe. In recent years, science has turned to the design of CubeSats, which beyond meeting daily needs, are also the cornerstone for the subsequent construction of new satellites, that will have the potential, at some later stage of the human history, to give a final answer to the aforementioned issues. The current thesis deals with the design of a 6U-XL CubeSat using laminated composite materials, which is planned to transport a deployable robotic arm in space. At a first stage, the appropriate literature overview is made, with a special reference to material science and especially to composites, which constitute both the present and the future of aerospace applications. Followingly, the primary structural components of the CubeSat, which were designed in CATIA environment, are presented and sufficiently commented. Then all the necessary analyses (modal, quasi-static, buckling and random vibrations), which confirm at least computationally the proper functionality of the satellite during the launch, are carried out in the MSC PATRAN/NASTRAN software. Finally, an attempt is made to optimize the present structure through the study of different composite materials with the aim of reducing the total weight of the satellite, which represents one of the most crucial driving-factors of every space mission.

Keywords

CubeSat, Computer Aided Design (CAD), Finite Element Analysis (FEA), Composites, Aerospace Engineering

DEVELOPMENT OF A DEPLOYABLE ORIGAMI TYPE ROBOTIC ARM WITH 3-D.o.F FOR SPACE APPLICATIONS AND TESTING OF A PROTOTYPE

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ABSTRACT

The exploration and understanding of space are perhaps more important than ever. Despite all of the progress in technology and our knowledge of space it still hides dangers for astronauts and crews, who make trips into space. Also, often the duration of the trips makes them prohibited for humans. For these reasons it is very important to promote the use of robotic systems which will be able to cooperate with humans or work autonomously. One of the big problems when it comes to space missions is the high cost of the mission all around. Another issue is the limited and very precious space that the rocket has. This diploma thesis focuses on the development of a deployable origami type robotic arm with 3 degrees of freedom for space applications. Firstly, there is bibliographic research of some existing robotic arms in space, deployable mechanisms and deployable robots. Then some concept design ideas are given, regarding the mechanism that that makes the arm deployable. Out of those ideas one is selected based on its practicality and overall feasibility. This concept design then goes through a process of improvement in order for it to work more efficient. After this process, a 3d representation is made of both the mechanism and the entire arm. Lastly, the robotic arm is kinematically and statically analyzed and a prototype of the mechanism is constructed via 3d printing.

Keywords

Deployable mechanisms, Robotic arms in space, Robots, Robots in space

STUDY OF BONDING REHABILITATION OF RC ELEMENTS WITH USE OF CONCRETE MORTARS

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ABSTRACT

Corrosion of steel reinforcement is one of the main causes of deterioration of the mechanical characteristics of the load-bearing structure of reinforced concrete (RC) structures. A widely known technique for the restoration of corroded reinforced concrete elements is carried out by using repair mortars.

The aim of this technique is to restore the bond between steel and concrete on the one hand, and to restore the original geometry of the structural element on the other.

Based on the lack of reference in the regulations regarding the degree of restoration, the purpose of this study is to quantify the degree of recovery of the bond strength of corroded reinforced concrete elements using repair mortars.

To this end, in the present experimental work, the corrosion damage of the steel encased in concrete, was induced in the laboratory by the accelerated corrosion method. Subsequently, part of the corroded specimens were repaired and then mechanical pull-out tests were carried out on all specimens. The mechanical performance of the repaired specimens was compared with the performance of corroded, unrepaired specimens and also with the performances of uncorroded specimens.

From the results of the present study, it was shown that the correct use of the special repair mortar, in combination with the thickening and shaping characteristics of the interface of old concrete and repair mortar, significantly improved the degraded strength of the adhesion bond. It should be emphasized that the type of shaping (geometry of the concrete surface section) of the steel coating, had a significant effect on the degree of bond strength's recovery.

In conclusion, it was determined that in order to more fully quantify the magnitude of the restored bond strength in corroded RC elements, more experimental tests will be required.

Keywords

reinforced concrete, corrosion, bond strength, mechanical properties, repair mortars, degree of recovery, mechanical pull-out tests.

EXPERIMENTAL BIOMECHANICAL STUDY OF FEMUR BONE WITH INTERTROCHANTERIC FRACTURE WITH AND WITHOUT IMPLANT

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ABSTRACT

Intertrochanteric fractures in human femurs are the most common mode of failure in terms of mechanics, especially if they are affected by osteoporosis. A femur is considered a natural composite material and can be used in biomechanical studies for data collection and characterization of its behavior under loading. With proper design, the loads, and the way they are applied, can approximate those that the bone receives from the human body during daily activities.

An experimental biomechanical study of this kind was carried out in the context of this Diploma Thesis, where bone loads in single leg standing, walking and fracture were approximated. Three femur bones made of composite materials, constructed in such a way that they present the osteoporosis phenomenon, were used for the above loadings, using a customized device for the machine's grips to impose the loads. In two of the three, the Gamma3 and TRIGEN INTERTAN implants were placed, in order to observe their behavior during the presence of an intertrochanteric fracture, which was artificially created afterwards, and to compare them with the behavior of the intact composite femur.

From the load application machine's data useful diagrams were constructed to compare the applied load with the displacement received by the composite femur. By placing three strain gauges at points of interest and frequent failure observation, the deformations that occur during load application were extracted. The results were compared with those obtained from the Digital Imaging Correlation System that was installed and recording alongside the strain gauges, while the system also helped with the information collection of the deformations' and displacements' distribution on the inner face of the bone.

Keywords

Composite Materials, Composite Femur, Biomechanical Experimental Study, Strain Gauges, Digital Imaging Correlation

NUMERICAL DETERMINATION OF THE STRAIN ENERGY RELEASE RATE, COMPARISON WITH THE J-INTEGRAL AND USE OF METHODS FOR CALCULATING THE EFFECTIVE CRACK LENGTH IN MODE I FRACTURE MECHANICS EXPERIMENTS

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ABSTRACT

In this work, a numerical investigation of the fracture behavior of two different adhesive joints is done using finite element methods for delamination assessment under pure mode I loading. The first joint is a dissimilar and unbalanced adhesive joint between thin titanium and CFRP adherents, that is destined for application in the future aircraft's leading edge. This joint is reinforced from both sides with two aluminum beams to increase its flexural stiffness. For this joint, both two-dimensional and three-dimensional finite element analyses were performed due to its complexity. The second is a similar and balanced one and consists of two UD-CFRP sub-laminates which are being co-cured with the adhesive film to conclude to the final joint under study. Only two-dimensional finite element analyses were performed for this joint due to its symmetry. The finite element analyses made using cohesive zone modeling, virtual crack closure technique and contour integral analysis to capture the fracture behavior of these joints under pure mode I loading. A comparison of the different effective crack lengths calculated by various analytical equations for the compliance from the literature, is made for each joint. The calculation of the effective crack length is very useful in cases where it is not possible to measure the crack length during propagation, such as mode II experiments, or in cases where secondary cracks appear, as in the case of TiCoAJo. In addition, with the effective crack length concept it is accounted the fracture process zone effects. Also, a comparison between J-Integral and strain energy release rate calculated by different methods, is made for each joint. Finally, the results of the finite element analyses are validated with the experimental results.

Keywords

Composite Materials, Fracture Mechanics, Effective Crack Length, Secondary Cracks, Cohesive Zone Model (CZM), Virtual Crack Closure Technique (VCCT), J-Integral

FRACTURE BEHAVIOUR OF ADHESIVE JOINTS UNDER HIGH STRAIN RATE LOADING CONDITIONS

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ABSTRACT

The current diploma thesis is a comparison of the influence between quasi-static and high strain rates conditions, in a mode I interlaminar strength on adhesive joint of a titanium and a carbon fiber reinforced plastic alloy. A literature review took place in order to find the characteristics of the best pattern for digital image correlation (DIC) and analytical solutions that described entirely the experiment as well, to export essential data. In quasi-static experiments the force displacement curves were exported. The compliance was calculated from the analytical models. Using an analytical model to calculate the rotations of the adherents, and the experimental rotations which were measured from the DIC, the strain energy release rate was measured via Jintegral. Consequently, the dynamic experiments took place in order to estimate the dynamic strain energy release rate using the DIC method in a Split Hopkinson Pressure Bar configuration and also for comparison between static and dynamic results.

Keywords

Fracture Mechanics, Dynamic Strain Energy Release Rate, Strain Rate, Adhesive Joints, Data Reduction

DEVELOPMENT OF NANO-REINFORCED TENSYLON PANELS FOR ANTI-BALLISTIC PROTECTION

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ABSTRACT

The discovery of innovative and novel materials and processes at the nanoscale has provided enormous opportunities for the development of new nanocomposites in all fields that will help to upgrade our lives. In recent years the applications of nanotechnology in the field of defense industry and in particular for the improvement of personal anti-ballistic protection has attracted great interest. In recent years we have witnessed a more intensive process for the improvement and development of more efficient and lightweight personal anti-ballistic protection systems. The basis for this development of anti-ballistic vests is composite materials with polymeric matrix, specifically Tensylon. In particular, the polymers that find application in such properties are thermoplastics. Tensylon is ultra-high molecular weight polyethylene (UHMWPE) which has demonstrated superior anti-ballistic properties than any other material. The development of nanotechnology and the creation of nanocomposite materials with a polymeric matrix has given hope for further improvement of anti-ballistic plates for personal protection. Materials such as graphene, carbon nanotubes and generally any other nanoscale material are a matter of interest for such research in the defense industry. The purpose of this thesis is to enhance the anti-ballistic behavior of the ballistic armor panels from Tensylon with the use of nanomaterials. To reinforce the panels, surface modification of Tensylon fabrics was performed using particles from nano-reinforced and thermoplastic materials. Three (3) kinds of 3-layer structures were developed, one using only Tensylon base material (NEAT), the other with embedded polyamide reinforcement powder (GRILTEX 1330) nano-modified with 10%wt – multi-walled carbon nanotubes (MWCNTs) and the last one, with embedded polyamide reinforcement powder (GRILTEX 1516) nano-modified with 10%wt – multi-walled carbon nanotubes (MWCNTs). The amount of nano-reinforced material placed in the back two (2) Tensylon layers of each structure is 10 grams per square meter (gsm). Then followed the preparation process as well as the conduct of high-speed impacts to check and evaluate the two developed materials in terms of their anti-ballistic behavior. After conducting the required tests, the necessary results were extracted, based on which two (2) separate cases were established, even though the amounts and content of the nano-reinforced thermoplastics in each structure were the same. In the 1st case, the presence of polyamide reinforcement powder (GRILTEX 1330) with nanomaterials (carbon nanotubes) in the Tensylon base material, introduces additional absorbing mechanisms to the material and improves its ballistic behavior by absorbing greater amount of energy. In the 2nd case, the presence of polyamide reinforcement powder (GRILTEX 1516) with nanomaterials (carbon nanotubes), did not lead to the desired results and degraded the ballistic behavior of the material.

Keywords

Composite materials, Polymer materials, Nanotechnology, Defense, Antiballistic vests

INFLUENCE OF SHOT BLASTING ON MECHANICAL PERFORMANCE OF STEEL REINFORCING BARS B500c AND THEIR CORROSION RESISTANCE

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ABSTRACT

As is widely known, the long-term performance of reinforced concrete structures (RC) is evaluated by two main criteria, serviceability and durability. Serviceability relates to structural integrity, the ability of the element to withstand loads throughout its life and perform its intended function. Durability refers to the ability of the material to resist changes in its microstructure and properties, particularly when these changes may adversely affect the serviceability of the element. Thus, RC structures need significant maintenance due to the harmful effect of corrosive agents on the reinforcing steel, gradually degrading both the mechanical properties and ductility, which is crucial to ensure the load-bearing capacity of the elements and thus the mechanical performance of O/S structures. In the light of this, various direct or indirect methods of corrosion protection of steel are adopted by the scientific community in order to delay the occurrence of corrosive phenomena in steel reinforcement. In the present experimental work, the influence of shot blasting by use of olivine and glass bead on the corrosion damage of steel reinforcement and its mechanical response, both under monotonic loading and low cycle fatigue conditions, is studied. A total of 200 steel reinforcing bars of nominal diameter 12 mm were used for the laboratory study. The specimens were arranged in two rows of specimens, one of which constituted the tensile specimens with a total length of 50 cm and the second row constituted the fatigue specimens with a total length of 20 cm, respectively. Each series was divided into two categories, the bare and the shot blasted specimens. For the simulation of corrosive environment conditions XS1, according to KTX 2016, accelerated corrosion experiments were carried out by keeping the specimens in a salt spray chamber for exposure times of 30, 60, 90 and 120 days. Upon completion of the corrosion experiments, mechanical tensile and low cycle fatigue tests were performed with imposed strain ranges of ±0.5%, ±0.75% and ±1.25%. Examining the results of the mechanical tensile tests, it is obvious that the application of shot blasting, at short exposure times, does not significantly affect the mechanical response of steel reinforcement. On the contrary, the experimental results of the low cycle fatigue tests, show a slight improvement of the shot blasted specimens at short corrosion times, both in their service life and in their ability to absorb energy, compared to the bare specimens. Finally, based on the fatigue damage index presented in terms of mechanical performance, the superiority of the shot blasted specimens emerged. The application of this particular method of shot blasting, improved the service life of steel reinforcement, which was reflected in all tested imposed deformation amplitudes.

Keywords

reinforcing steel, corrosion, shot blasting, monotonic loading, low-cycle fatigue conditions

DEVELOPMENT OF A METHODOLOGY FOR THE VALIDATION OF FULL-FIELD DISPLACEMENT MEASUREMENT METHODS

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ABSTRACT

The present diploma thesis aimed to quantify the measurement ambiguity of a DIC (Digital Image Correlation) device by conducting experiments. The device has the ability to take full field measurements. The applied method was based on displaying undistorted and distorted spot patterns on a moving and non-moving LCD screen and then measuring the imposed displacements using the DIC system. The data collected can be useful in confirming the measurement ambiguity of the DIC device. Two types of experiments were conducted. In the first type, a laboratory tensile device was used on the mobile part, where a screen was placed. The LCD screen displayed a speckle pattern, which is used in the DIC method, while the monitor displacement was controlled with high accuracy by the tensile device. In the second type, to avoid the constrains of the first experiment, a device was designed to move the screen in two dimensions, while these displacements with accuracy. The data collected from both experiments were used to assess the measurement accuracy of the DIC device.

Keywords

Digital Image Correlation (DIC), full field measurement, displacement measurement, uncertainty quantification

NUMERICAL AND ANALYTICAL MODELING OF THE VIBRATION RESPONSE OF GRAPHENE ON A POLYMER

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ABSTRACT

Since its discovery in 2004, graphene has attracted the interest of the scientific community due to its exceptional properties. It is considered that graphene is the thinnest, strongest, most flexible, and most conductive -electrically and thermally- material ever discovered. Graphene is being examined by different scientific fields, not only giving significant improvements to already existing applications, but also solving problems that had not been addressed until now. Despite the difficulties so far, the practical and commercial usage of graphene is expected to be imminent and ambitious.

This thesis consists of three main sections. In the first section, the oscillatory response of a graphene membrane supported on a substrate is studied. Firstly, the structure is being analytically studied, by constructing suitable equations that describe the vibrational response of graphene and the substrate, according to the non-local theory of elasticity.

The analytical model is then examined numerically through finite element analyses. To determine the oscillatory behavior of the finite element models, modal analyses are performed. The deviations that arise between those two types of analysis, the analytical and the numerical analysis, lie in the fact that the finite element methods approximate models based on classical elasticity theory.

In contrast to the classical theory of elasticity, in which the medium is considered absolutely continuous and does not depend on the scale at which it is examined, the non-local theory of elasticity implements the nano-scale effect and takes into consideration that the behavior at a point in a medium, it is affected by the state of all the points of the medium. That is, it introduces the concept of interaction between the points of the medium.

To continue with, a model of a graphene membrane, to which a point mass is attached, is studied. Correspondingly to the previous section, the graphene-mass model is approached analytically, with equations describing the vibrational response of the system, based on the non-local elasticity theory. Furthermore, the graphene-mass system is analyzed numerically with finite element models. The graphene sheet is modeled in two (2) ways in the finite element

analyses. Firstly, it is modeled as a continuous sheet and then, the atomic structure of the hexagonal lattice of a graphene is modeled to represent the sheet.

Finally, a combination of the two analyzes described above, leads to the modeling of a system of a graphene based on a polymeric substrate, to which a point mass is attached. Founded on this model, in the last section of the thesis, an elementary form of a mass detection system, i.e. a sensor (resonator), is being studies. In the resonator model gas molecules are attached, and the oscillatory response of the system is numerically studied in finite element analysis.

Keywords

Graphene vibration, vibrational response of graphene, graphene-polymer, graphene-substrate, graphene with attached-mass, nonlocal theory of elasticity, graphene resonator

COMPUTATIONAL CHARACTERIZATION OF IMPACT DAMAGE IN THE LOCAL, TRANSIENT AND QUASI-STATIC IMPACT REGIME IN LAMINATED COMPOSITE PLATES

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ABSTRACT

The application of composite materials in various structures has created the need to study their mechanical behavior and predict the damage that may occur to them. A common use of composites is the manufacturing of laminate boards that can be used in the aviation industry, motor sports, etc. One of the most common forms of loading is impact from foreign bodies, such as hail on an aircraft fuselage. Due to the wide range of uses of composite laminates, impact conditions vary significantly between applications, and for this reason their impact loading has been categorized into local, transitional and pseudostatic, based on their impact response. The investigation of interlaminar and intralaminar failures of the composite in the entire spectrum is a necessary condition for their safe use, as well as the effect the intralaminar failure has on the damage of the interfaces.

In the context of this Thesis, the finite element method was used to analyze the effect of the impact of a laminate made of composite fibrous material, by a spherical indeformable impactor with various velocities and masses, in order to simulate different cases covering the spectrum of the three types of impact mentioned. The plate under study is an orthotropic laminate consisting of layers of epoxy resin reinforced with carbon fiber, and more specifically of the composite material "CARBON FIBER (Tenax HTS40 12 K 300)/EPOXY (Cycom 977-2)" with a density of 1600 kg/ m3. The dimensions of the plate are 75x125 mm with variable thickness depending on the case, and its edges are simply supported. The layer sequence of the laminate is [0/45/90/-45]S. In order to study the interlaminar failure at the micro-scale level, the micromechanical method of Tsamis was applied, which used the mechanical properties of the fiber and the matrix to calculate the properties of the laminas of the composite. For the failure of the finite elements in terms of matrix or fiber, the Maximum Stress failure criterion was used in combination with the strengths obtained from the micromechanical method of Tsamis. Interlaminar delamination damage was investigated by applying the interlaminar failure criterion of the Cohesive Zone

Model. To achieve all of the above, the Abaqus/Explicit software was utilized, a computational package that allows the analysis of engineering problems using Finite Elements. Tsamis' micromechanical method was implemented as a VUMAT subroutine in the package, and the results were visualized in Abaqus for optimal understanding.

The results of the investigation consist of the interlaminar, fiber and matrix failure of the laminate layers for each of the simulated impact cases, as well as the delamination of the interfaces, extracted from a model that does not consider intralaminar damage. The conclusions of the work include the matching of interlaminar and intralaminar failures with the type of impact, the effect of the existence of fiber and matrix failure on the interlaminar delamination, the influence of the variation of the thickness of the plate and the impactor radius on the extent of the damage.

Keywords

Impact, local, transitional, pseudostatic, micromechanics, Finite elements, composites, intralaminar damage, interlaminar delamination, laminates

ANALYSIS OF STRUCTURAL DAMAGE EFFECTS ON THE DYNAMIC RESPONSE OF A WINDTURBINE BLADE

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ABSTRACT

During the last decades, the need for renewable energy that has lower environmental impact has increased exponentially, drawing the attention of the scientific and industrial community towards the wind energy sector and leading them to put some serious effort on the development of larger and more efficient wind turbines as also dedicated analysis and design tools.

The main aim of the present Diploma thesis is the development of a Reference Wind Turbine blade's numerical model and the implementation of structural dynamic analyses in order to evaluate the structural damping effects and the structural integrity of the blade. In this work, the basic theoretical background related to the wind turbine blades' structure and aerodynamic loads is provided, along with a brief presentation of the modelling methods that are used for the simulation of the blade's dynamic response. Dedicated wind turbine simulation tools are examined regarding their framework, as well as the aerodynamic and structural theories and approaches they employ for the simulation of the entire mechanism. The theoretical part of this thesis is completed with the review of composites' loss factors and proportional damping, while the definition of Rayleigh factors that will be utilized in the numerical models is correlated with modal damping properties. It should be highlighted, that the modal damping factors are determined from experimentally calculated damping properties, using the DAMPBEAM code. Before the description of the blade's model, a brief review of the two numerical tools (hGAST that is used for the calculation of the aerodynamic loads, and DAMPBEAM that is used for the determination of modal damping factors) that provide data for the modeling and structural assessment of the component takes place. During the definition of the wind turbine's blade model in Abaqus, the CAD model is created, material properties and composite layups are defined, available dynamic analysis methods and procedures are examined, load modeling is described, and the meshing strategy is explained. The implementation of modal analysis provides the eigenfrequencies and eigenmodes of the structure that are successfully compared with the respective ones from the DAMPBEAM code. For the damping assessment, various dynamic analyses are performed, where different aerodynamic load-cases, damping properties and analysis methods are employed and their results are compared, extracting important conclusions for the effect of each parameter. Finally, the effect of dynamic damping on the structural integrity of the blade is examined based on (1) the Tsai-Wu criterion and the (2) the maximum strain failure criterion, and the results confirm the ability of the structure to cope with the loading conditions of the simulated operation

Keywords

Wind Turbine Blade, Composite material, Finite Element Methods, Damping, Dynamic Simulation, Dynamic stresses, First-ply-failure

DEVELOPMENT OF MULTIFUCTIONAL THERMOPLASTIC MATERIALS BY USING GRAPHENE-BASED NANOSPECIES

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ABSTRACT

This diploma thesis deals with the study and preparation of composite materials from thermoplastic materials (HDPE, Griltex) reinforced with graphene nano-particles (MWCNTs, GNPs). The work focused on the smooth conduct of the manufacturing process, for the preparation of the desired nano-reinforced materials (Griltex_13%MWCNTs, Griltex_10%MWCNTs, Griltex_10%GNPs and HDPE_10%MWCNTs) followed by the experimental characterization of these materials. To investigate the multi-functionality of the developed specimens, mechanical tests as well as measurements of electrical and thermal conductivity were performed. The manufacturing of the specimens was done using injection molding method, utilizing a specially designed set up.

Initially, in the context of the work, after a bibliographic search that was carried out, reference is made to thermoplastic materials and materials belonging to the category of polyamides, to fundamental definitions and information on composite materials, their categories and their processing methods. After that, the structure and characteristics of carbon and its derivatives are described in detail, with emphasis on carbon nanotubes (CNTs) and multilayer graphene (GNPs), presenting their manufacturing techniques and processes. In addition, the production methods and extrusion systems of complex thermoplastic materials as well as the laboratory device used in the laboratory are indicated.

In the experimental part of the work, the processes carried out in the laboratory for the preparation of materials are presented and the process of preparing the composites is described, through the injection molding device. The main challenge was the homogeneous dispersion of nano-particles inside the material as well as the avoidance of the systoms that the graphene nano-particles tend to create. The results of the experimental tests carried out in the laboratory show that the addition of MWCNTs and GNPs inside the thermoplastic materials has positive impact. The mechanical properties were significantly improved, with the Young Modulus and Tensile Strength increasing as the concentration of nanoparticles increases, while the

Fracture Strain on initially seemed not to be affected by the addition of multilayer graphenes but then with the addition of MWCNTs it was significantly degraded. Finally, Thermal Conductivity was improved significantly in all cases while Electrical Conductivity was improved by about 10 orders of magnitude with the addition of MWCNTs only with the addition of MWCNTs.

Keywords

Thermoplastic Polymers, Nanocomposite Materials, Mechanical Properties, Electrical Conductivity - Thermal Conductivity, Carbon Nanotubes-GNPs

DAMAGE DIAGNOSIS ON STIFFENED COMPOSITE PANELS UTILIZING MACHINE LEARNING ALGORITHMS

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ABSTRACT

This thesis studies and compares Classification models. The purpose is to find the most efficient Classification model, which will perform Classification predictions, having the most accurate results. The entire study was carried out using Matlab software.

First, the various categories of Machine Learning are reviewed, such as Supervised Learning, Unsupervised Learning and Semi-supervised Learning, while the Classification models are presented, with which the study will be carried out.

Then, a literature review is carried out on models such as Decision Trees, Support Vector Machines (SVM), k-Nearest Neighbors models, Ensemble Classifiers, Neural Networks and others, while at the same time, the advantages and disadvantages of each model are highlighted.

The presentation of the study begins with the creation of three versions with data from the finite element model of a reinforced composite panel subjected to axial compressive loads. The first stage of the study was to decide which version of data is the best to use for training the Classification models.

Then, based on the selected data version, all the Classification models available in the Matlab software were trained. Then, a comparison was made based on specific criteria, which concern the accuracy in category predictions, but also the percentage of correct predictions of each category. In this way, the most efficient model was selected, which is capable of returning the most accurate predictions.

Finally, using this model, 1172 predictions were made with values obtained from the experiment panel. The data were split into two groups, one group containing 485 values and the other 687 values, in order to confirm the validity of this model. Thus, it is possible to evaluate if the trained model is capable of predicting the damage presence in the panel.

Keywords

Classification, Diagnosis, Composites, Machine Learning, Supervised Learning

INVESTIGATION OF ELECTROMECHANICAL ENERGY HARVESTING PERFORMANCE OF SPECIAL SETUPS WITH PIEZOELECTRIC STACKS

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ABSTRACT

The demand for sustainable energy sources in order to power electronic devices or to store energy for future use has prompted researchers to seek appropriate/efficient solutions. Recent progress in Material Science has enabled manufacturing of piezoelectric materials of increased efficiency. Such materials can produce electrical energy when subjected to mechanical strain. Thus, energy harvesting with piezoelectric elements, parasitically, from ambient oscillations, is an especially attractive solution.

In the present diploma thesis is presented a special oscillatory energy-harvesting setup, equipped with piezoelectric stacks. The performance of this setup is being investigated for an energy-harvesting circuit with solely resistance as well as inductance and resistance combined. Within the framework of the current study a computational tool is developed, capable of simulating the dynamic behaviour of the energy-harvesting device. Our target is to be able to use the computational tool so as to determine the conditions for optimal electrical power generation.

For the mathematical modelling of the system an electromechanically coupled, linear second-order ordinary differential equation system, which is solved in Matlab, is developed. Subsequently the magnitude of the dynamic response of the system is calculated and presented with respect to the acceleration of the auxiliary mass of the device, the voltage of the energy-harvesting circuit as well as the harvested electrical power, for a range of values of resistance and inductance.

The theoretical model of the system is experimentally validated for a range of values of resistance and inductance. Indeed, the comparison between theoretical and experimental results justifies using the computational tool for a first estimate of the optimal values of resistance or inductance, as well as the excitation frequency of the base of the mechanism, for which the harvested electrical power is maximized. Moreover, the special piezoelectric setup in this study can yield considerable amounts of power, especially in the case of an inductive circuit.

In conclusion, the proposed piezoelectric energy-harvesting device is quite promising and it should be further investigated in order to unlock its full potential.

Keywords

energy-harvesting setup, oscillations, piezoelectric elements, electrical circuit, power optimization, computational tool.

STUDY OF NANOMECHANICAL PROPERTIES OF MATERIALS USING ATOMIC FORCE MICROSCOPY

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ABSTRACT

In this diploma thesis we obtained 3 UHMWPE hip arthroplasty articular cup specimens after extraction from patients due to chronic or acute infection. We analyzed them using an Atomic Force Microscope (AFM) and Nanoindenter instrumentation system to study their morphology and nanomechanical properties on each side of the cup. The specific properties which we studied include roughness Ra and RMS, elastic modulus Er, storage modulus E', loss modulus E'' and loss factor tanδ. The range of RMS roughness per scan area for AFM is for 1μm [81.662-279.69]nm, 4μm [199.540-564.9]nm and 16μm [647.51-2238]nm. The corresponding Ra roughness value ranges are [41.82-180.5]nm, [156.94-290.84]nm and [489.16-1840]nm. The range of values per maximum Quasistatic Nanoindentation (QSM) force for the modulus of elasticity Er is for 600μN [38.57-706.99]MPa, for 3000μN [90.51-1220]MPa and for 5000μN [104.6-506.83]MPa. The corresponding ranges of loss factor tanδ obtained by Dynamic Nanoindentation (DSM) are [0.062-0.158]MPa, [0.084-0.198]MPa, [0.098-0.216]MPa. Correlating the values of roughness, elastic modulus and loss factor we determined the size and type of wear on each set of UHMWPE samples and in co-operation with the specialized surgeons we can estimate the effect of the type of infection on the damage of the implant.

Keywords

AFM, Nanoindentation, UHMWPE, Hip arthroplasty, Viscoelastic

INVESTIGATION OF THE EFFECT OF GRAPHENE-BASED NANOSPECIES ON THE DAMAGE TOLERANCE OF FIBROUS COMPOSITE MATERIALS UNDER STATIC AND DYNAMIC LOADING

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ABSTRACT

In the last decades, an extensive use of composite materials has been observed in a multitude of construction fields, while at the same time they are also attracting the interest of the scientific community. This lies in the amazing properties presented by the combination of the individual components of the composite material.

The object of this study work is the development of a new generation of materials with improved fracture properties. In particular, a study was made of the effect of graphitic nanoparticles (thermally reduced graphene oxide, rGO) on the damage tolerance of polymeric matrix fibrous composite materials under static and dynamic load conditions.

Initially, elements of the theory of composite materials are mentioned regarding their structure, how they are categorized, the properties and advantages resulting from the combination of their individual components, as well as their fields of application. In addition, the interest that graphene attracts as a reinforcing agent in composite materials, improving the properties of the final product, is noteworthy.

Thus, composite materials, CFRPs (Carbon Fiber Reinforced Polymers), Uni-Directional (UD) were prepared. Two categories of fibrous composites were prepared. The first category includes the preparation of CFRPs (Carbon Fiber Reinforced Polymers) with epoxy resin for matrix (neat), while in the second category an additional 0.5% wt. of graphene nanoparticles is added (doped).

The mixture of epoxy resin with 0.5% wt rGO powder, it was mixed uniformly with the use of a calender (Three Roll Mill) and constituted the doping of the polymeric matrix. The two epoxy resins, nanomodified and non-nanomodified, were used to impregnate the carbon fibers to prepare the prepregs. The two laminated plates were obtained by cutting the prepregs into layers and placing the layers sequentially on top of each other.

Afterwards, the polymerized laminated plates (neat and doped) were subjected to non-destructive ultrasonic testing (C-scan) to characterize their quality. Then, the samples were cut to specific standards, which were subjected to experiments.

Finally, the fracture tests mode I and mode II under static load were performed on the samples, which determined the critical strain energy release rate, GIC and GIIC respectively. Also, the experimental procedure was completed with mode I fatigue, where the onset of interlaminar delamination was determined. The mentioned mode I, II static fracture tests and mode I fatigue tests were carried out based on the ASTM D 5528, Airbus AITM 1.0006 and ASTM D 6115–97 standards respectively. The results come from the comparison of the doped samples with the reference samples (neat samples).

The data collected from the static fracture tests did not present major changes in the fracture properties. In detail, in the type I experiment the GIC strain energy release rate decreased by 3.5%, while in the type II experiment the GIIC strain energy release rate increased by 3%. Regarding the fatigue fracture mechanics experiments, in the first phase the critical strain energy release rate GIinit was obtained, by re-conducting mode I static stress tests, an increase in load cycles at 180,6% and 110766,66% for the initiation of interlaminar delamination was observed at loading levels of 50% and 80% of GIinit , respectively.

Keywords

Composite materials, epoxy resin, carbon fibers, graphene oxide, nano-enhancement, fracture

SIMULATION OF LASER SHOCK-INDUCED DISASSEMBLY OF COMPOSITE STRUCTURAL PARTS

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ABSTRACT

Nowadays sustainability has become a necessity, in terms of material development and processing, especially regarding recycling. However, most of the materials used currently are designed decades ago, meaning they do not follow the environmentally friendly standards, that are implemented in today's methods. That's why there are methods being developed to reuse those components, as a form of recycling.

The recycling of composites, especially, that consist of two phases, the fibers and the matrix, is considered of high importance, though very challenging. In order to disassemble the structural components of these materials, the laser shock method has been proven effective. In this method, high intensity laser interacts with the front face of the material and this interaction creates the shock wave, which propagates through the thickness of the material. When the reflections of the wave overlap with each other, tensile stresses are developed and if they exceed the threshold of the material's strength, damage occurs.

This essay is focused on the investigation of this phenomenon. Chapter 1 introduces us to the basic concepts of the study and it transitions from the developing of the composites to their dismantling processes. In Chapter 2, the theoretical background is analyzed, regarding the laser principle, the cohesive zone method and the use of equations of state to describe different materials. In Chapter 3, the process of developing a finite element model is described, as well as the material models and the basic orders that were used in the LS-Dyna program. Chapter 4 describes the validation process between the experimental and the simulation results that are obtained for a single shot. Also, different parameters are changed and their influence on the shock wave behaviour is discussed. In Chapter 5, a study is performed in terms of using a double shot and calculating the time delay of the second pulse, in order to induce damage. In Chapter 6, after selecting the optimal time delay, which gives the greater damage, a study undergoes so that the damage propagates. In Chapter 7, the conclusions that are extracted, as well as proposals for future studies are discussed.

Keywords

numerical simulation; finite element analysis; cohesive zone modeling; shock wave propagation; laser-induced shock; CFRP composites; bonded structures.

NUMERICAL SIMULATION OF ADHESIVE JOINTS UNDER HIGH STRAIN RATE LOADING

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ABSTRACT

In this thesis, the numerical study of the response of anadhesive joint, under static and high-rate loading is presented The joint consists of two dissimilar adherents, a Titanium and a CFRP (Carbon Fibre Reinforced Plastic). The developed numerical models are calibrated using the experimental eigenfrequencies and a hybrid analytical experimental method. To begin with, a modal analysis is presented to find the eigenfrequencies and eigenmodes of the joint specimen. Then, the finite element models created are presented in order to model crack propagation using the VCCT (Virtual Crack Closure Technique) method under static and dynamic loads. By using experimental data, the calibration of the models is achieved and the critical SERR (Strain energy Release Rate) is found for each loading case. The second part of the thesis presents a chapter dealing with the fractography analysis of the fracture surfaces of the specimens from the static and dynamic experiments. The fracture mechanisms that prevailed in each of the specimens are compared using optical and electron microscopy.

Keywords

Virtual Crack Closure TechniqueStrain Energy Release Rate, Finite Element Analysis, Fractography, Delamination

NUMERICAL SIMULATION OF THE LASER SHOCK STRIPING PROCESS OF AIRCRAFT ALUMINUM SUBSTRATES

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ABSTRACT

Nowadays composite materials tend to be used more and more, especially in applications where there are increased requirements, such as aeronautics and power generation. One of the most common classes of composite materials encountered in aeronautics is fiber reinforced laminated composite materials. The commonly used materials in these applications are polymeric epoxy resins in the role of the matrix material and carbon fibers in the role of reinforcement (Carbon Fiber Reinforced Polymer, CFRP). Paints, which are often epoxy, are used, in order to protect the materials of the structural parts of the aircraft from environmental conditions. However, during the life of the aircraft, paint stripping is necessary, as several times various structural elements need restoration, maintenance and regular inspection. Various paint stripping methods have been used in the aeronautic industry, such as the chemical paint stripping, which presents various health and environmental problems. Thus, the interest of researchers has turned to paint stripping using laser shock wave. This method has been used successfully in metallic plates, but its use in composite materials is particularly complicated. The main focus of his thesis is the simulation of the laser shock paint stripping process on CFRP laminate, through Finite Element Analysis (FEA). Firstly, the aim of this thesis is to validate the finite element model of a CFRP plate for shock wave loading, comparing the FEA model results with experimental data. The finite element analysis of the CFRP is held in the computer program LS-DYNA, where the orthotropic elastic material model MAT_002 and the composite damage model MAT_162 are used. Furthermore, a parametric study was carried out for the model of the CFRP laminate with a paint layer. In this case, the material models that were used are the material model MAT_162 for the CFRP laminate, the elastoplastic hydrodynamic material model MAT_010 for the paint layer and the mixed cohesive zone model MAT_138 for the plate-paint interface. The parameters that are significant for this study are the applied pressure of the shock wave and the thickness of the paint layer. The objective of this parametric study is to find the appropriate parameters, so that there is the maximum possible peeling of the paint layer, with the least possible failures in the CFRP laminate. Finally, the results of the parametric study analyzes and the conclusions are presented.

Keywords

Laser shock, Paint stripping, Shock wave propagation, Composite material, Finite Element Analysis.

DIVISION OF DESIGN AND MANUFACTURING (SEPTEMBER 2022)

DETECTION AND LOCALIZATION OF SIMPLE AND MULTIPLE DAMAGES IN A COMPOSITE BOOM OF AN UNMANNED AERIAL AIRCRAFT VIA THE FUNCTIONAL MODEL BASED METHOD

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ABSTRACT

The problem of damage diagnosis with more emphasis to the precise localization (coordinates determination) of double-site damages via the Functional Model Based Method (FMBM) is investigated in the present study. The considered structure in this thesis is a real-scale (length 2.57m, mass 3569 gr) composite beam with orthogonal cross section (0.08m x 0.115m) which is part of the tail of a twin-boom Unmanned Aerial Vehicle (UAV). Small masses (28.3gr) are used on the structure simulating early stage, non-destructive, damages that affect locally the dynamics. These damages may be single (one mass) or double (pair of masses) and are placed on various locations along the beam on one or two sides. The force excitation to the beam is random white noise, and it is not used for damage diagnosis, while two random vibration response signals are recorded from two accelerometers. Measurements are received from a large number of experiments (1321) under "healthy" (no masses) and damaged (Single-Site or Double-Site) state of the structure.

The modelling of the Transmittance Function (TF) is achieved through corresponding parametric Transmittance Function AutoRegressive with eXogenous excitation (TF-ARX) model. The specific type of model uses a pair of response signals in order to eliminate uncertainties (e.g. different frequency content) associated with the excitation. Damage detection is based on the parameters of the TF-ARX model, which is initially estimated using signals from the "healthy" state of the structure, and in the sequel they are compared via a proper statistical hypothesis testing with

the parameters of a corresponding model, estimated from signals obtained from the structure under “unknown” state.

Damage precise localization (coordinates estimation) is achieved using the Functional Model Based Method (FMBM) which is based on Functional Models (FP models), which are like the TF-ARX with the important difference being that their parameters are functionally depended to the damage coordinates on the beam. Thus, two scalar functional models (FP-TF-ARX) are estimated in the training phase of the method for the representation of the structural dynamics under single-site damages (SSD) on each of the two beam sides, while three vector-dependent models (VFP-TF-ARX) are estimated for the representation of multi-site (MSD) damages (double), on each side and combined to both of them.

The detection results are excellent as 100% correct damage detection with zero false alarms is achieved. Moreover, the damage characterization results of all considered damages, as SSD or MSD, are very good achieving 97.62% of correct characterization, while damage coordinates estimation is accomplished with mean error 3.96 ± 2.92cm expressed in terms of the Euclidean distance from the actual damage location. In particular, the mean localization error for the considered SSDs is 2.84 ± 1.13 cm, whereas more precise localization is achieved for SSDs on the same beam side with the sensor where the error is 1.55 ± 1.02 cm. Finally, higher mean error (5.68 ± 4.84 cm) is observed for the considered MSDs located on different sides of the considered structure.

Keywords

Damage detection and precise localization, Simple and double early stage damages, Real scale composite beam, Statistical time series analysis, Vibration based Structural Health Monitoring (SHM), Functional Model Based Method (FMBM), Transmittance Function (TF), Unmanned Aerial Vehicle (UAV)

AUGMENTED REALITY APPLICATION FOR OPERATOR SUPPORT DURING ASSEMBLY PROCESSES BASED ON ENVIRONMENT PERCEPTION

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ABSTRACT

In recent years the market needs have created high demands for the industrial production lines. Both customization and rapidly changing market conditions have increased the complexity in the manufacturing field and have resulted in smaller products life cycles. Businesses cope with these new demanding conditions through the implementation of Industry 4.0 technologies and hybrid manufacturing systems. In this context, it is obligatory for modern operators to manage recurrent product changes and high complexity of modern manufacturing systems. The subject of this diploma thesis focuses on the design, development, and implementation of an augmented reality application for operator support based on environment perception. The application consists of several modules, namely: a) projector-based augmented reality support b) computer vision for assembly component detection, b) vision-based hand-tracking for operator action monitoring and human system interaction. The system is implemented on a human robot collaboration assembly cell deriving from the automotive industry. The effectiveness of the system and its submodules is evaluated in terms of usability, accuracy and productivity proving that the system can meet industrial requirements and be implemented on manufacturing lines.

Keywords

operator support, projection-based augmented reality, object detection, assembly instructions, human robot collaboration, hand recognition

OPTIMIZATION OF MECHANICAL SPRINGS BY GENETIC ALGORITHMS

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ABSTRACT

The present thesis presents the spring design problem and its optimization using genetic algorithms. The purpose is to examine the results and the perspectives provided by the use of these algorithms in the specific problem, applying them in various individual cases. Initially, a spring design problem is presented with the results provided by the application of various evolutionary algorithms and a brief description is made according to the data of the relevant technical literature. Then the relationships that govern the design and calculation of various types of springs are analyzed. References follow to the processes of parametric design and optimization, and the methods that are available are listed. The theory of genetic algorithms follow and references are made to their individual elements that will be used for solving the problems that follow.

Four different spring design cases are studied, and in each one of them the parameters, variables, and constraints, as well as the objective function for which the optimization is performed, are recorded. A complete analysis of the results of the genetic algorithm is done for each case through the values of the final solutions and the various diagrams concerning the way in which the algorithm works. All available data from the process are examined in order to draw the necessary conclusions regarding the use of genetic algorithms in the specific problem. At the end, some general conclusions, and further perspectives for the continuation of this work are given.

Keywords

design, springs, parametric design, optimization, genetic algorithms

DEVELOPMENT OF A ROBOTIC PNEUMATIC FINGER WITH EMBEDDED SOUND SENSOR FOR TEXTURE RECOGNITION OF FLEXIBLE OBJECTS THROUGH FRICTION

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ABSTRACT

This thesis focuses on the construction of a pneumatic robotic grasping finger capable of imitating the biological limb's movements and tactile properties, aiming at automating flexible objects' handling process. In particular, the proposed finger adequately mimics a human finger both by approaching the working surface and by palpating and differentiating fabrics. This addition to the textile industry, contributes directly to the increase in productivity, therefore also to the reduction of products' cost, while it aims toward the elimination of human recourses' chronic strain employed in such professions.

First, reference is made to the anatomy and structure of human finger, while previous research on approaching both movement and palpation of flexible objects through various artificial subsystems is presented. The bibliographic research completes with the categorization of the fabrics according to structure and method of weaving.

The main part focuses on the design and construction process of the proposed finger. The operating criteria and design specifications are presented, with the help of which the mechanical designs of the final construction and the 3D molds that shape the finger are made. Further on, its fabrication steps are listed, and the correct operation of the actuation and sensor is controlled. Finally, the artificial finger is held on an improvised device, while it is rubbed against 10 different fabrics.

The results indicate that the proposed finger has a smaller range of motion compared to human's, even though each joint is actuated separately. As for the sense of touch, the finger is capable of differentiating objects with distinctly different roughnesses, while it lags in separating fabrics of similar roughnesses.

Keywords

Fabric recognition, Pneumatic finger, Soft finger, Sound Sensor, Robotic gripper.

DEVELOPMENT OF A DATA DRIVEN SIMULATION TOOL FOR LASER WELDING APPLICATIONS

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ABSTRACT

The manufacturing industry is heading from mass production to the mass customization era, depending on the dynamic customer needs. A major part of this transition is reconfiguring the production to adapt to this dynamic market. Laser welding is an important manufacturing process for industry, as not only is more accurate than any other welding process, it is also very fast. Simultaneously, the physics that govern the process, are numerous and complex, which makes the selection of correct process parameters difficult, when it alternates constantly. Simulating the process could be a valuable tool for the industry for solving the above-mentioned problem, as physical tests could be avoided, which are rather costly and time-consuming. But the existing simulation tools do not cover fully the industrial needs, as these either require a lot of computational time or either too complex to use.

In this diploma thesis, a data-driven simulation tool for the laser welding process has been developed, and its main goal is to cover the industrial need, which is the accurate, fast, and simple prediction of the process's behavior, during a reconfiguration scenario. First, the existing solutions have been examined and analyzed, and the gap between those solutions has been identified. Therefore, the simulation of the process has been carried out in two commercial finite element analysis software tools and used to produce process-related data. Then, through machine learning these data have been used, to create two reduced-order models of the process. The first model is responsible for predicting the distortions of T-shaped geometrical features of a product, while the second model is responsible for predicting the weld bead geometrical characteristics achieved during welding, based on the selected process parameters, and the product's geometrical features and specifications. In parallel, per the model, the respective way of adoption and use by industry has been developed, based on the industry's needs.

Keywords

Mass customization, Production reconfiguration, Laser welding, Simulation, Reduced order models

DESIGN AND SIMULATION OF A GREENHOUSE IN A COMPUTER ENVIRONMENT (ANSYS/FLUENT) AND AN AUTOMATIC CONTROL SYSTEM IN A LABVIEW ENVIRONMENT

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ABSTRACT

Greenhouses have been a good solution for increasing agricultural production since ancient times. In today's age with the development of technology, we are offered the possibility of their development and automation. Many studies are done on the automatic control of their microclimate, whether energy, numerical, or experimental, from intelligent control systems to cfd analyses, with the main purpose of optimal control of the microclimate and at the same time saving energy.

This thesis concerns the process of modelling, design and simulation of an automatic control system in greenhouses. More specifically, a virtual greenhouse (digital twin) is designed, and in it the natural phenomena that take place in a real greenhouse are simulated. The program used for the simulations is Ansys fluent, suitable for cfd analyses, in which with the use of udf, code written in c, some actuators (window, air heater) are controlled, to control the microclimate of the virtual greenhouse. In this thesis we make use of a branch of artificial intelligence, fuzzy logic, which is a method of replicating human thinking. Fuzzy logic has applications in automatic control. To find the optimal control system, four fuzzy controllers are tested, and the optimal control system that the simulations will indicate will be implemented on an Arduino board using the LabVIEW program. The control will specifically be done at the temperature of the plants' space (inside the greenhouse), with real weather data from a real greenhouse, which was provided to us by the co-supervising professor of the diploma course, Angeliki Kavga.

Keywords

Greenhouses, Ansys Fluent, LabView, Arduino, Fuzzy logic

APPLICATION OF GENETIC ALGORITHMS FOR THE OPTIMIZATION OF THE VIBRATIONAL BEHAVIOR OF MECHANICAL SYSTEMS

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ABSTRACT

In recent decades, there has been a demand for the development of practical, cost-effective control system applications that properly address the negative effects of vibration and protect various machines from natural or man-made hazards. For this reason, vibration control has received considerable research attention. Vibration control devices can be divided into three categories called passive, active and semi-active control systems. A parallel development in the last two decades has been the emergence of the field of computational intelligence (CI) consisting mainly of the three fields of neural networks, evolutionary computing, and fuzzy logic. This study focused on the application of genetic algorithms (GAs) to optimize the vibration behavior of two types of mechanical systems, a single-degree-of-freedom (SDoF) vibration system and a mechanical system with a dynamic vibration absorber (DVA) that are both widely used as vibration isolation devices. In addition, a passive vehicle suspension system was modeled, and the system was optimized to check the reliability of the genetic algorithm. Finally, suitable user-friendly Suitable graphical user interfaces (GUIs) were created by applying the above optimization process, to train users in both the theory of oscillations and the understanding of the theory of genetic algorithms. From a technical point of view, this research argues that the use of GA to find optimal solutions in oscillation control cases can be a reliable and well-performing tool that can contribute to the training of people interested in such educational fields.

Keywords

Vibration Control, Genetic Algorithm, Dynamic Vibration Absorber, Passive Vehicle Suspension System, Graphical User Interface

DEVELOPMENT OF A SMART GRID DIGITAL TWIN FOR ENERGY DISTRIBUTION. OPTIMIZATION: A PSS APPROACH

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ABSTRACT

With the urgent issues of lack of energy and environment pollution, in combination with the rapid increase of energy demand, due to the overpopulation of cities, a lot of pressure is put in the current electrical grids. At the same time, a massive flood of digital data is generated which makes analysis more complex. It is urgent to find sustainable solutions to meet the customers' demand in electric power. The 4th industrial revolution started the shift towards digitalization, decentralization and renewables among others, so new technologies and ideas were developed. In the recent years smart grids and Digital Twins (DT) are proven increasingly important. A smart grid is an electrical grid that includes several advanced technologies, such as smart metering, to achieve bidirectional communication and exchange of data between stakeholders, in order to fulfill their needs in the most efficient way. The DT model is a virtual representation of the physical electrical grid that communicates with each other and realizes its performance in live time. The DT helps the energy suppliers to monitor, analyze and predict possible events in the power grid. Through simulation new techniques and ideas can be tried out, for optimization without disturbing the actual system. Therefore, the proposed DT methodology can be realized as a service that analyzes data and gives valuable information in order to distribute energy, while minimizing the cost and protecting the environment, as a PSS model defines. The aim of this research work is to develop the DT of the electrical grid of a university campus showing the new features, possibilities, and advantages it can offer for maximizing the energy efficiency.

Keywords

Smart grid, Digital Twin, Energy distribution, Industry 4.0, PSS

MODELLING OF CONTACTS IN ELASTOHYDRODYNAMIC LUBRICATION UNDER THE EFFECT OF ROUGHNESS AND APPLICATION ON ROLLING BEARINGS

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ABSTRACT

Rolling bearings are critical machine parts, as a result the study of this mechanism is very significant. The aim of this study is to understand the significance of lubricant on the function of the bearing. To achieve this, some figures are created from the simulation that takes part.

First of all, some historical information is mentioned as far as the development and usage of rolling bearings are concerned. In addition, the advantages and disadvantages of them are mentioned.

Afterwards the basic categories of lubricants are described which are the liquid, solid, gaseous and grease. Then the thin and thick lubrication film are described.

In the next chapter emphasis is given to the lubrication mechanisms which are the boundary, the mixed, the elastohydrodynamic and the hydrodynamic. Because this work based on elastohydrodynamic lubrication, more information about this is given. Initially, historical data are given, then formulas which describe this mechanism as well as parameters that determine the pressure distribution and the thickness of the lubricant.

In chapter 4 the theory of Hertz for contacts is described. More specifically, the relations for calculating the contact width, the equivalent modulus, the maximum deformation and pressure are quoted.

Next in chapter 5 are mentioned all the relations required for the description of the mechanism of elastohydrodynamic lubrication. More specifically, the relations which are mentioned are those of the viscosity, the film thickness, the density and the balance of forces in the cylinder.

In the following chapter, roughness is analyzed. More especially, the parts of roughness are explained. After that, the four basic parameters which describe the roughness film are given. Then a curve is presented which describes in a satisfying manner the roughness. There are two

methods that measure the roughness and they are analyzed below. In the end of the chapter, it is attempted to connect the roughness with the objective of the current work.

Then the geometry of the model, the created mesh, the initial and boundary conditions and finally the simulation results are presented. After that, the effect of roughness and type of lubricant on the pressure distribution and the film thickness is examined, quoting relevant diagrams from the simulation.

Keywords

Elastohydrodynamic lubrication, roughness, pressure distribution, rolling bearings, film thickness

DIVISION OF ENERGY, AERONAUTICS AND ENVERONMENT (SEPTEMBER 2022)

COMPUTATIONAL STUDY OF A VERTICAL AXIS WIND-TURBINE OPERATING IN AIR-SAND PARTICLES TWO-PHASE FLOW

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ABSTRACT

The subject of this thesis was the computational investigation of the aerodynamic behavior of a Savonius-type (S-type) vertical axis wind turbine in a two-phase air-sand particle flow. The aim of the study is to understand the theoretical background of the operation of the Savonius wind turbine as well as the single-phase and two-phase behavior. Also, this work aims to find the static torque coefficients, cm, at the different operating angles of the wind turbine for single-phase airflow and two-phase air-sand particles flow. Finally, a comparison was made between the results of the single-phase flow with the corresponding results of the two-phase flow in order to study the effects of the two-phase air-sand particles flow on the wind turbine static torque coefficient.

The air-sand particle two-phase flow is a complex phenomenon, the mechanisms of which are not fully understood. It can be considered as incompressible thin air transport, with air as the carrier fluid and sand particles as the transported matter. The model with which the phenomenon was examined is the discrete two-phase flow (DPM). In this model the secondary phase was considered dispersed within the primary phase and the interaction forces with the surrounding flow are calculated for each particle.

The simulation was done using the Ansys computing platform, specifically through the commercial Computational Fluid Dynamics (CFD) package Fluent, where through the computer code the transport and conservation equations of the single-phase flow were solved for steady flow and then, after convergence and stabilization of the flow was achieved, the introduction of the sand particles through the Discrete Phase Model was chosen as mentioned above. The

modeling was done in a two-dimensional (2D) model and after a grid independence study, a grid of 80000 cells was chosen as the most suitable.

In this thesis, a total of 14 single-phase flow simulations using two turbulence models, Realizable k-ε and SST k-ω, as well as 14 two-phase flow simulations using the SST k-ω turbulence model, for concentrations sand particles Q=0.01 kg/s and Q=0.1 kg/s were carried out. The simulations were done with wind speed u=7 m/s, where the Savonius wind turbine works most efficiently, for 7 different operating angles of the wind turbine blades 0º, 30º, 50º, 90º, 120º, 150º and 180º.

Finally, the results of the above simulations are presented and commented on for the various static torque coefficients, cm, as well as for the pressure and velocity distributions of each angle.

Keywords

Computational study, vertical axis wind turbine, Savonius, two-phase flow, sand particles

2-D SIMULATION OF INCOMPRESSIBLE FLUID FLOW USING THE FINITE VOLUMES METHOD

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ABSTRACT

The diploma thesis investigates heat transfer via diffusion and convection in two dimension using the finite volume method. To solve the convection and diffusion equations, the Upwind method and the FTCS method were chosen. For the creation of the mesh and the discretization of the domain, a vertex centered finite volume mesh was used, with the centers of the border cells located at the vertices of the cells. As initial conditions, a uniform temperature was set for the entire domain. Dirichlet conditions were applied on the boundaries. Three of the borders were set with the same temperature as the initial conditions, whilst the fourth was set with a different temperature, from which boundary heat starts to flow. For the creation of the domain and it's meshing, solving the equations and extracting data, a program written in Python was created, in which the user, following the program's instructions, uses the command line via inserting simple instructions. Thus, the user can simply and efficiently run many different simulations, while hardly interfering with the code.

Keywords

Implicit, Convection and Diffusion, Python, 2D, Curved Geometry

STUDY OF COMPRESSIBLE FLOW FIELDS AND SENSORS FOR DETECTION OF FLOW FEATURES

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ABSTRACT

The present work lies in the area of computational fluid mechanics and in particular in the area of flow feature detection. The methods of flow feature detection are encountered in many applications for the study of flow fields, such as computational grid adaptation, control for local addition of artificial dissipation to numerical schemes, study of the physics of a flow field based on experimental measurements, as well as training and evaluation of "machine learning" techniques, such as neural networks. Detection of the local flow features is of particular value for compressible flows, in which multiple flow phenomena of different intensity and topology usually coexist, and interact with each other.

In the present work, compressible flow fields with multiple coexisting flow features are studied. The phenomena include boundary layers, flow separation regions, vortices, jets, wakes, as well as supersonic flow phenomena such as shock waves, expansion / compression waves and contact discontinuities. An appropriate "intensity index" is defined for each type of flow feature. Detection of the flow features and their interaction regions is carried out with specially formulated functions (sensors / indicators), which are based on the spatial variation of a wide range of flow quantities. Composite indicators are also employed, which combine elementary single-quantity sensors, and are capable of detecting multiple features. The sensors are evaluated with a quantitative method and appropriate metrics of their performance are presented. The evaluation is based on the application of the indicators to a wide range of computational flow fields, which are simulated with flow-solving software. In addition, an analytic expression is proposed for the automatic determination of the detection threshold, i.e. a critical value for each sensor above which a flow feature is considered to take place. The analytic expression is based on the statistical parameters of the sensors and the shape of their distributions. The thesis is completed with the application of sensors for the local refinement of computational grids.

Keywords

compressible flows, flow feature detection, composite sensors, grid adaptation, flow visualization

HEAT TRANSFER ENHANCEMENT INVESTIGATION USING INTERANL HELICAL FINNED TUBES

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ABSTRACT

Heat exchangers are devices designed to transfer heat to or from a system and are among the most encountered in technical structures. Therefore, there is great interest and there is constant research to optimize their performance which results, among other things, in reducing the cost of construction, operation and the size of the facilities. This diploma thesis deals with the investigation of the enhancement of the heat transfer rate using micro-fin tubes. Initially, an introduction is made to thermal exchangers and methodologies that enhance the heat transfer coefficient are presented, while then the paper focuses on shell-tube thermal exchangers that use internal pipes with internal coils to enhance the heat transfer rate, technology which gives satisfactory results based on previous research. The aim of the diploma thesis was to study and design an experimental arrangement of shell-tube exchanger using an inner tube with micro-fins and to compare the performance with a corresponding smooth tube. Devices that included inner tubes with coils that have different geometric characteristics (helix height e, angle of helix a, number of fins Ns) were studied in order to investigate their effect on the transfer coefficient heat and the extra pressure drop caused. This was followed by the design of the shell-tube exchangers with water as a working fluid in antiparallel flow with the ability to adjust the initial conditions of the experiment in a wide range of values (Reynolds number 15000-33000, flows 0.055 kg/s –0.107 kg/s with temperature of the hot fluid from 40-60 °C. The design of the device includes the measurement system with a series of instruments (thermocouples, flow meters, differential manometers, etc.) to collect the necessary experimental results. In addition, a theoretical study was made of the devices based on computational models for the heat transfer coefficient and pressure drop. Subsequently, the experimental devices were constructed and the experiments were carried out in the range of conditions mentioned above and the requested results were extracted. Based on the resulting diagrams, we conclude that the number of Nusselt in the alternator with internal coils is about two times greater while the pressure drop is 1.5 times greater compared to the exchanger with smooth tubes and its performance is higher than the efficiency of smooth alternator in the entire range of experimental measurements. Finally, proposals are made for expanding and optimizing research.

Keywords

Heat Transfer, Heat Exchangers, Micro-fin tubes, Heat Exchanger Design, Nusselt Number , Pressure Drop

NUMERICAL STUDY OF THE IMPACT OF PLANT-COVERED BUILDINGS ON THE URBAN ENVIRONMENT

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ABSTRACT

The present thesis focuses on the groundbreaking subject of buildings coverage with vegetation as a green solution for the problems of urban environment. The study of this topic, in general, is at an early stage and its efficiency is still being researched with various studies being conducted globally. In this study were gathered data from the existing scientific literature, so that the bibliographic part would be as complete as possible, which is the start for a correct and complete numerical study afterwards.

In the first part of this thesis, an extensive discussion is made concerning the plant coverage systems for buildings, which are divided into vertical and horizontal. Then, the characteristics of each category are fully analyzed, especially the technical ones, regarding their needs and the selection criteria for their installation are described. Afterwards, the advantages of each category are presented and so do their contribution to energy saving and "relief" from the problems of the urban environment. At the same time, full reference is made to the types of vegetation and the characteristics that they are required to meet because vegetation is one of the most important factors that will determine the success of the green building. This part of the thesis concludes with the description of additional special plant coverage systems, such as sky gardens/bridges and green balconies and full reference is made to the combination of plant coverage with photovoltaics, an innovative green solution that seems to have many advantages.

In the second part of the work, all the "tools" used during the numerical study are analyzed. Specifically, the open-source software OpenFOAM which is the one that was used to conduct the study, the way it operates and its features. The terms and models used were mentioned, terms related to atmospheric air flow, equations that govern this flow and turbulent flow models. Finally, the concept and terms related to the vegetation cover of the buildings such as leaf area density LAD were fully analyzed.

In the third part of the thesis, the numerical study and the steps followed during its conduction are thoroughly analyzed. In addition, the results of the CFD simulations carried out are listed figuratively. In a few words, during the study a city was simulated along with the conditions that prevail in it, such as wind flow, radiation, and heat transfer. Then the green gardens of different leaf area density attached to the buildings were simulated. Finally, in comparison with the absence of building vegetation in the same city the conclusions of the numerical study were extracted, and future work was proposed.

Keywords

OpenFOAM, CFD, Plant building coverage, Vegetation, LAD

NUMERICAL INVESTIGATION OF FLOW CONTROL OVER A WING WITH ACTIVE DIMPLES

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ABSTRACT

This diploma thesis is a computational analysis of flow control over a wing with shaping options of its upper surface. Specifically, it investigates how a grid of dimples or bumps on the upper surface of a wing affects the wing's aerodynamic characteristics under specific conditions. The primary objective is to mitigate the severe losses in flow when the boundary layer separates after a certain angle of attack. Because of the drag reduction, an improvement of the wing's aerodynamic characteristics (e.g., aerodynamic efficiency, stalling angle) is expected. Many methods and mechanisms were developed to reduce drag on the wing. The most promising method is "flow control", where the separation of the flow's boundary layer is either eliminated, or the separation point is moved downstream along the wing's surface due to the use of active or passive mechanisms (e.g., advection or suction of the flow, artificial deformation of the surface).

The design of this study's mechanism uses the "flow control" method. The array of dimples or bumps is generated on the standard NACA0018 wing geometry, and affects the flow's boundary layer and subsequently the wing's aerodynamic characteristics. The dimples' and bumps' geometrical characteristics are chosen for "geometry-optimal" results based on related previous research. This study also outlines the construction and configuration of the array of dimples or bumps on the wing, i.e., the topology, arrangement, the number of cavities on the wing's upper surface, and the selection of the wing, as developed in a previous thesis on the topic. The mechanism's effect on the wing's aerodynamic characteristics is assessed with the computational fluid dynamics method using the ANSYS-Fluent computer program. A flexible simulation model of the wing with/without the mechanism in a range of angles of attack is used. The steps, conditions, theories, and methods used in this computational aerodynamic model are presented (e.g., fixed geometrical characteristics of the dimples/bumps, steady state of the flow over time, boundary conditions, flow analysis method). The model's results and corresponding diagrams are also listed. The conclusion of analysis is that the most optimal wing shape under these specific conditions is the geometry with the bumps. They offer overall better aerodynamic performance for the analyzed range of angles of attack, although both dimples and bumps showed an increase of the stalling angle.

Keywords

Flow control, Computational aerodynamic analysis, ANSYS-Fluent, NACA0018, Surface morphing with a grid of dimples

COMPUTATIONAL STUDY OF A VERTICAL AXIS WIND-TURBINE OPERATING IN AIR-WATER TWO-PHASE FLOW

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ABSTRACT

In this thesis, a study of single and two-phase air and air-water flow, respectively, was carried out in a Savonius type (S-type) vertical axis wind turbine, as well as the computational investigation of its aerodynamic behavior, in single and two-phase flow using the Ansys platform. The aim of the study is to understand the theoretical background of the operation of the Savonius wind turbine as well as of the single and two-phase behavior. Also, the aim of this work was to find the static torque coefficients (cm) of the wind turbine at various operating angles, for single-phase airflow and two-phase air-water flow in rainfall conditions. Finally, a comparison was made between the results of the single-phase flow with the corresponding results of the two-phase flow in order to analyze the effects of the two-phase air-water flow on the wind turbine static torque coefficient.

Air-water two-phase flow is a complex phenomenon, the mechanisms of which are not fully understood. It can be considered as incompressible air transport, with air as the carrier fluid and water particles as the transported matter. The model with which the phenomenon was examined is the discrete two-phase flow. In this model the secondary phase was considered dispersed within the primary phase and the interaction forces with the surrounding flow are calculated for each particle. This is how particles are introduced into the flow and then their trajectory was calculated as well as their interaction with the air (heat, mass and momentum transfer).

The simulation was done using the Ansys computing platform, specifically through the commercial Computational Fluid Dynamics (CFD) package, Fluent. In Fluent's computational code, the transport and conservation equations for single-phase flow are first solved for steady flow, and then, after convergence and stabilization of the flow was achieved, the introduction of water particles through the Discrete Phase Model (DPM) was chosen. The modeling was done in a two-dimensional model and after a grid-independence study, a grid of 80,000 cells was chosen as the most suitable.

In this thesis a total of 14 single-phase flow simulations using two turbulence models Realizable k-ε and SST k-ω, as well as 14 two-phase flow simulations using the SST k-ω turbulence model for water droplet contents LWC = 30 g/m^3 and LWC = 65 g/m^3 were carried out. The simulations were done with a wind speed of 7 m/s where the Savonius wind turbine works most efficiently, for 7 different operating angles of the wind turbine blades 0˚, 30˚, 50˚, 90˚, 120˚, 150˚ and 180˚.

Finally, the results of the above simulations are presented and commented on, for the various static torque coefficients (cm) as well as for the pressure and velocity distributions of each angle.

Keywords

Computational investigation, Savonius, vertical axis wind turbine, two-phase flow, water particles

EXPERIMENTAL INVESTIGATION OF THE OH*/CH* CHEMILUMINESCENCE RATIO IN AERODYNAMICALLY STABILIZED FLAMES, WITH INLET MIXTURE STRATIFICATION

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ABSTRACT

In the present Diploma Thesis, the theoretical background for the understanding of the phenomenology of the isothermal and the reactive field formed at the outlet of two high-speed coaxial flows is, initially, presented. In addition, the final results obtained through experimental measurements of the isothermal and mixing field and the emitted chemiluminescence of the reacting flow are presented and analyzed.

The studied stratified flames are aerodynamically stabilized in an experimental coaxial flow facility designed and developed at the Laboratory of Thermodynamics & Statistical Applications. In this experimental setup, low-velocity air is injected through an inner cylindrical duct and fuel of varying mass flow rates is supplied under different injection heights to control mixture stratification. High-velocity air flows into the outer cylindrical coaxial duct so that, due to the interaction of the two high-ratio streams, a central recirculation zone is created at a distance downstream of the exit plane, which forms a reverse flow region where the flame is anchored. Thanks to this arrangement, aerodynamic stabilization of a turbulent stratified flame is achieved, which ensures stable combustion of lean propane-air mixtures.

This study also presents the distributions of the equivalence ratio values in the area downstream of the experimental facility, as obtained using Fourier Transform Infrared Spectroscopy (FTIR). The effect of the fuel injection height on the stratification of the mixture upstream of the flame stabilization region is also analyzed. Chemiluminescence measurements (OH* and CH*) were then used to assess the effect of different stratification levels of the incoming mixture on the topology of the flames under study. Finally, an attempt was made to correlate the relative air-fuel ratio with the ratio of excited radicals OH*/CH* of the flame. This correlation was evaluated in relation to a corresponding literary mathematical equation derived from experimental data on laminar premixed flames, demonstrating the validity and prospects of the methodology followed

in the present work, to estimate the effective equivalence ratio through chemiluminescence emissions.

Keywords

Chemiluminescence, FTIR, Recirculation, Stratification, Coaxial Flow

SIMULATION AND COMPARISON OF LAMINAR FULLY-PREMIXED AND STRATIFIED RECIRCULATING PROPANE FLAMES STABILIZED DOWNSTREAM OF A PREMIXER GEOMETRY, WITH AND WITHOUT THE INFLUENCE OF HEAT TRANSFER

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ABSTRACT

Stratified flames are a category of flames with great theoretical and practical interest, as combustion efficiency and stabilization, as well as the emission of gaseous pollutants, can be optimized through their utilization. Contemporaneously, combustion in fully premixed flames takes place at lower temperatures, resulting in reduced NOx emissions and soot formation. As the modern combustion industry faces new challenges daily in order to reduce the greenhouse gas emissions, while simultaneously increasing the efficiency and flexibility of combustion equipment, attention has been drawn on lean combustion, with combustion systems that use either fully premixed or stratified combustion.

The present work describes an investigation of the effect of both flame category based on reactant mixing and conjugate heat transfer on the stabilization of a propane flame, under low Reynolds numbers. This study explores six different simulations for the same standard geometry, each time changing the flame type, the heat transfer condition between flame and stabilizer and the equivalence ratio, while keeping the oxidant inlet velocity constant. The two different flame types that will be investigated are the fully premixed flame and the stratified flame, while the two heat transfer conditions to be studied are either adiabatic or isothermal walls at a 600K temperature. The cases of equivalence ratio $\Phi = 0.6$ and $\Phi = 0.75$ will be examined while the oxidant inlet velocity will be constant and equal to $u_{in} = 0.7$ m/s in all cases. In each case the mixture temperature is set at 300K.

All simulations were carried out using the Laminar model, as well as the Species Transport model for a 48-element mechanism, as implemented in the commercially available software Fluent within the Ansys suite.

Keywords

fully premixed flames, stratified flames, conjugate heat transfer, equivalence ratio, propane

INVESTIGATION OF FLOW IN A VARIABLE CROSS-SECTION DUCT AND IMPLEMENTATION OF BERNOULLI AND THE CONSERVATION OF MASS EQUATIONS

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ABSTRACT

The current study aims at verifying the conservation of mass and Bernoulli equations by conducting a series of experiments carried out in the existing installation of the laboratory, which consists of a subsonic wind tunnel and a measurement chamber. The chamber consists of five specially shaped sections, three of which are constant cross-section and two that are variable, the first one acting as a nozzle and the second as a diffuser. The purpose of the experiments was to measure, the static pressures along the duct and the dynamic pressure perpendicularly to the constant sections. The measurements were taken using a Pitot - static tube and a differential manometer. The Pitot static along with its support mechanism could be moved into the holes that were opened at the top of the constant cross - sections and take measurements throughout their height. The experiments were carried out at six positions of the plant's resistance regulator. The results of the experiment are presented in tables. With the use of the Fluid Mechanics relations we calculated the theoretical values of static pressures for real and for frictionless flows, the results of which are compared with the experimental measurements. In addition, diagrams showing the distributions of dynamic pressure and fluid velocity are shown. The results were processed using EXCEL. Finally, conclusions and remarks follow.

Keywords

Duct flow, continuity equation, Bernoulli equation, Experiments, Pitot-static

COMPUTATIONAL INVESTIGATION OF WINGTIP VORTEX MERGING

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ABSTRACT

The present thesis refers to the merging of wing tip vortices and aims to create a computer simulation model of our phenomenon with the help of the Ansys Fluent package, in order to draw useful conclusions. The following summary is part of the thesis which and consists of the following chapters:

1st chapter (Description of the phenomenon)

In the first chapter we introduce the reader to the description of the natural phenomenon, how it is created and how it evolves, how important it is, what effects it has and we analyze some basic concepts and terms and characteristics of turbines and wings.

2nd chapter (CFD and fluid theory)

In the second chapter we mention basic concepts and terms of fluids and the field of computational fluid dynamics as well as simulation methods.

3rd chapter (Experimental data)

In the third chapter we refer to the experimental data on which our simulation was based as well as the experiment that was done, the sampling method and the results obtained on which our simulation is based and compared.

4th chapter (Computer simulation)

In this chapter we analyze the steps we followed in the ANSYS program in order to construct the geometry, the construction of our mesh, the introduction of the boundary conditions, and the selection of the appropriate turbulence model

5th chapter (Results and comparison of results)

This chapter presents the results of the simulation we followed regarding the velocities of our fluid and the quantitative and qualitative comparison of these results with the corresponding experimental ones.

6th Chapter (Recap)

In this chapter, the overall summary of the work is made, from the first introductory chapters to the results and ways to improve the reliability of the calculations.

Keywords

Wingtip vortices, Computational Fluid Dynamics, Ansys Fluent

COMPUTATIONAL STUDY AND COMPARISON OF THE FLOW AND THERMAL FIELD OF CURVED AND STRAIGHT TUBE THROUGH A PARAMETRIC INVESTIGATION OF THEIR BEHAVIOUR FOR DIFFERENT VALUES OF FLUID AND THERMAL CONDITIONS

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ABSTRACT

The subject of the present diploma thesis is a computational study about laminar and turbulent fluid flow through straight and curved ducts. Ansys fluent is a computational program used in fluid mechanics applications, which was also used for the study carried out in this thesis. The process in fluent starts by designing the geometries which in our case are a straight duct of circular cross-section and a curved duct (U-tube) also of circular cross-section. The next step is to create the appropriate mesh for each geometry, then we continue with the modeling part and the process ends with the results and the analysis. In this thesis, four Reynolds numbers (500, 1500, 3000, 8000) were used for both geometries and two different turbulence models (k-epsilon and sst k-omega) for the turbulent flows. The results in all flow cases revealed much better heat transfer to the center of the fluid in the case of the curved duct compared to the straight duct.

Keywords

curved ducts, turbulent flow, heat transfer, computational fluid dynamics, ANSYS-FLUENT

DEVELOPMENT OF ICT APPLICATIONS FOR INDUSTRIAL MACHINERY USING MACHINE LEARNING TECHNOLOGIES

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ABSTRACT

Industrial production in today's global market is more important than ever. Any breakdown and stoppage imply reduced revenue and delays. Digital technologies and especially machine learning contribute to the elimination of defects in production processes. All that thanks to the amount of valuable data collected. Therefore, machine learning, which allows the extraction of information from data, and its sub-categories with examples of algorithms in each are analysed in this paper. Then a real-world example of supervised machine learning is presented to identify process phase and criticality level in a dry granulation machine tool from a pharmaceutical company. In order to achieve this, Random Forest and Decision Jungle Algorithms are used. After that a real unsupervised machine learning problem is presented to categorize and evaluate the data from sensors in two bottleneck internal combustion engine production machines. The data is then classified into clusters using of the K-Means algorithm. Finally, code is developed in Python programming language according to the methodology of the first case study.

Keywords

Machine Learning, Industrial Machinery, Supervised Learning, Unsupervised Learning, Industrial Revolution

DEVELOPMENT OF AN OPTIMIZATION MODEL IN GAMS ENVIRONMENT FOR THE PRODUCTION PLANNING OF A STEEL TUBE MILL

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ABSTRACT

The aim of this thesis is to introduce the broad concept of Mathematical Programming, for creating a mathematical model based on real data given by an industry. The topic thesis encourages the reader to appreciate the importance of Mathematical Programming in optimizing manufacturing operations or reduce final product's price. Consequently, a more efficient operation and huge profits for the industry are attained. The paper provides the structure of an optimization model as well as the concept used to construct it. Readers will learn about the wide range of industry sectors in which mathematical programming may be used. Additionally, there will be cited instances when mathematical programming might offer significant answers to issues that a company encounters throughout operation and production planning. In particular, a model of mixed integer linear programming that aids the subject industry in the area of production programming and allows for flexibility in the face of several unexpected changes in the marketplace will be developed. The modeling system utilized throughout this thesis for mathematical programming and optimization is named gams, it may swiftly convert actual optimization issues from the actual life into computer code. Using the aforementioned studies, significant conclusions may be drawn.

Keywords

Mathematical Programming, Production planning, Storage, Steel tube mill, Mixed Integer Linear, Programming

TECHNOLOGY FORESIGHT FOR NICHES OF ENERGY SUSTAINABILITY TRANSITIONS: THE CASE OF GREEK ISLANDS

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ABSTRACT

This thesis focuses on the sustainable island energy transitions. More specifically, the work examines: a) the technologies of energy production, storage and use of in the island's energy system, b) the most important factors that influence the transition and c) the duration and the conditions, so that this transition takes place.

Methodologically, the work is developed in 3 stages. In the first stage, the socio-technical energy system of the Greek islands is analyzed at the level of production, diffusion and use of energy technologies, where its economic, political, social and technological characteristics are studied. In the second stage, a literature review is made of mature and emerging energy production and storage technologies that will be able to cover future energy demand. Innovative technologies for transportation in, to and from the island are also mentioned. Then, 3 scenarios for the future of islands energy systems are constructed with the tool of technology foresight in combination with the Basics scenario method. In the scenario development process, economic, social, political and environmental factors play an important role that influence the installation of green technologies. In the third stage, the dynamic evolution of these energy transition scenarios is studied through systemic dynamics. As an example, the dynamic model is implemented with the iThink software on the island of Sifnos.

The results of the scenario's simulations show that the energy transition to RES is gradual and is possible only in the case where the conditions of the economic situation, energy policy, technological development and social acceptance are favorable.

Keywords

Energy Sustainability Transitions, Greek Islands, Technology Foresight, System Dynamics, Scenarios Development