ABSTRACTS OF THE 4th EJIL

LAETA Young Researchers Meeting

4º Encontro de Jovens Investigadores do LAETA

BOOK OF ABSTRACTS

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PREFACE

The 4th LAETA Young Researchers Meeting (4EJIL – 4º Encontro de Jovens Investigadores do LAETA) is held from November, 9th to 10th of 2017 in Covilhã, Portugal. Since its beginning, the EJIL is a continuous source of sharing state-of-the-art developments in the scientific and technological fields of Energy, Transports and Aeronautics and a large number of applications in the field of Mechanical Engineering. This meeting also offers a unique opportunity for joining young researchers of LAETA (Laboratório Associado de Energia, Transportes e Aeronáutica) units, namely: IDMEC, INEGI, ADAI, and AeroG. One main objective of this meeting is the promotion and encouragement of interdisciplinary discussions among young researchers.

This Book of Abstracts contains the synthesis of the papers accepted for oral presentation and is organized by the Thematic Research Lines of LAETA, which cover the research fields of Energy, Aeronautics and Space, Advanced Manufacturing, Advanced Materials, Biomechanics, Fires, Engineering Design and Engineering Systems.

On behalf of the Organizing Committee, I would like to express our gratitude to those who contributed to the success of this meeting. The assistance provided by the Advisory Committee is highly appreciated. A special thanks also goes to the participants and the authors, without whom the 4EJIL, and this book, would not be possible.

And last, but not least, I would like to manifest my sincere gratitude to my colleagues of the Organizing Committee not only for the efficient work performed but especially for the friendly and helpfulness environment lived during the time of preparation of the meeting.

Covilhã, November 9, 2017

André R. R. Silva

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ADITIONAL INFORMATION

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ABSTRACTS OF THE TOPIC

ENERGY

COMPUTATIONAL MODELS FOR STRUCTURAL HEALTH MONITORING SETUP DECISION ON OFFSHORE WIND

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Keywords: Offshore Wind, Computer-aided Engineering, Supporting Structures, Finite Element Method.

Abstract.

Offshore Wind (OSW) is one of the most promising renewable technologies for the upcoming years, due to the generalized high-level winds and the extensive offshore area available for resource exploration. The costs associated with these technologies are yet, nonetheless, higher than those of other renewable technologies, such as onshore wind or PV solar, which is a consequence of the elevated costs of manufacturing, assembling, installation and O&M of these structures on offshore conditions. Cost reduction has been, then, the number one goal for OSW actors, which may be achieved by innovation or through scaling processes. Structural Health Monitoring (SHM) systems may be used as a tool for cost reduction, as they promote the use of condition-based maintenance strategies which are usually associated with decreased costs on O&M. Three different computational models for SHM setup decision based on Computer-aided Engineering (CAE) and Finite Element tools were developed, namely for the monopile foundation, the semi-submersible floating foundation and an innovative foundation for transitional waters. Foundation type, sea and wind states have shown to strongly influence the magnitude and type of loadings submitted to the supporting structures (tower and foundation). Preliminary results indicate that these models may serve as basis for SHM setup decision prior to installation. Further research is suggested on the correlation between computational and experimental data.

HETEROGENEOUS BASIC CATALYSTS FOR BIODIESEL PRODUCTION

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Keywords: Biodiesel, Heterogeneous basic catalysts.

Abstract.

Current society presents high energy consumption with a tendency to need even more and more energy. Nowadays, almost all the energy comes from fossil fuels, contributing to anthropogenic carbon emissions and, consequently, to the greenhouse effect. Moreover, according to the British Petroleum Company, at the consumption rate of 2015, the total proven oil reserves will only ensure the next 49 years.

Biodiesel, a mixture of Fatty Acid Methyl Esters (FAME), is a feasible renewable substitute for diesel fuel since its employment does not require any modifications in the engines. Biodiesel production is attained by a homogeneous basic catalyzed process using vegetable oils as feedstock. This process raises several social and technical issues. On the one hand, the use of feed crops to biofuel production, which can be avoid by recycling low-grade fats. On the other hand, the wastewater generated in the purification steps, and the impossibility of reusing the catalysts make biodiesel production process less attractive due to the high price of the final product.

Heterogeneous basic catalysts allow the simplification of downstream steps for biodiesel production since the catalyst can be easily removed from the reaction medium by filtration and the obtained products do not need any treatment aiming their neutralization. Therefore, production costs can be minimized through the elimination of some steps needed in the homogeneous catalysis. Another advantage of heterogeneous catalysts is the possibility of reusing them, subjecting them to simple regeneration processes or even without any regeneration treatment.

Among the heterogenous basic catalysts studied, calcium oxide has gained special attention because it is cheap, presents high catalytic activity and can be obtained from natural resources, as limestone, mollusk and bivalve shells, and eggshells. The calcium carbonate rich materials can be calcined to produce CaO. This possibility of reuse food wastes allows to a more sustainable process, and, at the same time, eliminates the disposal problem of these wastes.

In this study, catalysts were prepared from scallop shells and biodiesel was obtained using pork lard and pork lard/soybean oil mixtures.

BIODIESEL FROM SUSTAINABLE RAW FATS

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Keywords: Biodiesel, Waste animal fats.

Abstract.

Nowadays, most of the energy is based on fossil fuels. Such dependence has a negative impact both on the environment and economy, becoming unsustainable. Biodiesel, a mixture of fatty alkyl esters (FAAE), is a renewable substitute for fossil fuels. The most common process for biodiesel production is by methanolysis of vegetable oils using homogeneous basic catalysis. Vegetable oils are expensive and raise sustainability issues due to the use of arable lands, which may be used to food crops production.

In order to improve the biodiesel sustainability and reduce the production costs, biodiesel can also be produced with different waste animal fats (WAFs). Beef tallow, pork lard, poultry fat and grease are examples of animal fats that can be employed. Biodiesel produced from animal fats has a higher cetane number (advantage) comparing with fuels made from vegetable oils. However, because animal fats have a significant content of saturated fatty acids the produced fuel presents a higher cloud point (disadvantage).

Due to the high content of free fatty acids (FFA) and water present in animal fat, when using basic catalysts in the transesterification process, the FFA react with the catalyst forming soap. This leads not only to the loss of catalyst but also to a reduction of the FAME yield.

In this study, sustainable biodiesel was produced from low grade fats (beef tallow) over calcium based catalysts prepared by calcination of scallop shells. In order to minimize the drawback of using low quality fats, the fats were co-processed with soybean oil in combination with co-solvents.

ENHANCEMENT OF HEAT TRANSFER IN OFFICE BUILDINGS DURING NIGHT COOLING – REDUCED SCALE EXPERIMENTATION

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Keywords: Night Cooling, Suspended Ceiling, Natural Ventilation, Sustainable Buildings.

Abstract.
Most office buildings are designed to be ventilated and cooled using mechanical systems. In a temperate climate, when the outdoor temperatures are favourable, e.g. at night, passive ventilation and cooling techniques can be used to reduce energy consumption. Building's thermal mass represents a way to accomplish that goal due to their ability to retain heat. However, the portion of exposed elements in modern constructions is kept to a minimum. There are decorative components, like the suspended ceiling, that represent an insulation between the internal occupation zone and the thermal elements, preventing the desired thermal exchange. In this work, an innovative solution that optimizes the night cooling phenomena is presented. It is concerned with the use of the plenum formed by the space between the slab and the suspended ceiling for cooling purposes. The tests were carried on a reduced scale model based on dimensional analysis and similitude criteria. The suspended ceilings used in the experiments allow the outside air to cool the slab, therefore promoting an increase of the heat exchanged between the structural elements of the building and the zone that needs to be cooled. The results indicate that the increased amount of exposed slab area contributes to lower the day peak indoor temperatures.

ENERGY SUFFICIENCY IN THE BUILT ENVIRONMENT

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Keywords: Energy sufficiency, climate change, sustainability.

Abstract.

Climate change has already had significant impacts on the environment, with GHG emissions associated with human activities since the mid-20th century considered as the main cause of this problem. Numerous energy scholars, industries and policymakers have promoted energy efficiency as the main strategy to lower global GHG emissions in order to minimize the effects of climate change. However, thus far this strategy rather than leading to a state of affairs where the same, or lower, levels of final services are delivered with a lower energy input (i.e. by reducing energy demand), it has instead generally led to a situation where more services are provided with the same, or often higher, energy input (rebound effect). Consequently, energy policies and plans rolled out in the past couple of decades have had a limited impact on the overall GHG emission levels. In our work, we propose the use of energy sufficiency as the starting point for energy policies and strategies that aim to lower the environmental impact of energy systems. In effect, the focal point shifts away from the supply side, conversion devices and technological improvements – which are the main targets of efficiency improvements - to measures that target the demand side at the point where the useful energy is linked to final services. We present a general framework for energy sufficiency, building on the extensive literature of sufficiency as applied to other areas of knowledge such as sociology, economics and ecology. We apply this approach to the built environment, using the building sector as a case study and discuss shifts in energy policy that could lead to effective strategies to lower environmental impacts of future energy systems.

DESIGN OF AN EXPERIMENTAL FACILITY TO STUDY THE AERODYNAMICS BREAKUP OF A SINGLE DROPLET

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Keywords: Experimental, Aerodynamics Breakup, Droplet, Jet-Fuel.

Abstract.
The development of a spray since the early stages of liquid injection is driven by a set of parameters such as the pressure of injection, the characteristics of the injector nozzle and the properties of the surrounding environment where the droplets are inserted. The latter aspect -- in which the presence of a cross-flowing gas may be considered -- greatly influences the course of the spray evolution without the need to directly interfere with the injection system. In fact, the pressure distribution around the drop due to the relative velocity between gas and particle is responsible for the emergence of instabilities that may lead to deformation and disintegration into smaller fragments. This process is referred to as secondary atomization.
Several authors reported the existence of two stages of atomization: the primary breakup and secondary breakup. In practical applications, as e.g. direct injection engines and gas turbines, the combustion efficiency is dictated by the vaporization rate which, in turn, is influenced by the fuel spray atomization. Therefore, the comprehensive understanding of the breakup mechanisms and the characteristics of the resulting elements is essential to make it possible to develop highly efficient systems that rely on the atomization process.
The main objective in the study of the deformation and breakup mechanisms is to determine the final droplet size in order to introduce these data in spray impingement models. This goal has been proved very difficult to achieve due to the number of parameters that has a direct effect on the spray behavior. Furthermore, besides the influence of the aerodynamic forces in the deformation response, the way those forces are applied to particles also affects secondary atomization. In the present work, an experimental facility is design and built to study the deformation and breakup of a jet-fuel single droplet injected into a cross-flowed air stream in order improved our in-house developed breakup model.

BiSI - Biofuel Spray Impact in Aero-Engines

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Keywords: Biofuels, Spray, Aero Engines.

Abstract.
The successful adaptation of low emission aero-engines combustors to burn biofuels requires an adequate assessment of their performance for clean and efficient energy production. However, alternative fuels such as these depend on the technological development of aero-engine spray systems. Therefore, the work presented shows the BiSI project current stage of applying biofuels to injector design in aero-engines. An experimental characterization of the droplet/spray impingement processes, as well as the impact of multiple drops regarding hydrodynamic and heat transfer phenomena. And, finally, the physical and numerical modeling of droplet/spray impingement processes.
The biofuel selected was NESTE's NEXBTL HVO based on the similarities between its thermophysical properties and those of the Jet Fuel. The purpose is an appropriate assessment of their use in aero-engines, piston engines, and gas turbines.
The first part of the project consisted in the design and building of a new multiple impinging jets injector, with the possibility of accommodating up to 12 jets, including a central air jet to assist atomization, allowed investigating the performance of this atomization strategy and compare conventional jet fuels to fuel-biofuel mixtures. The spray characterization used a Laser diffraction technique to measure the Sauter Mean Diameter (SMD) in each nozzle geometric configuration (2, 3 and 4 simultaneous jets) and operating conditions.
In the second part, the validation of numerical models for describing the outcome of droplet/spray impingement events considered several fundamental experiments designed and built to measure the size and velocity of droplets before impinging on surfaces. Additionally, the work includes the use of high-speed visualization to: identify droplet-wall impingement regimes; characterize the size and velocity of droplets emerging from a secondary atomization after impact; investigate the hydrodynamics of a droplet impinging onto a dry flat surface through a cross-flow, or a liquid film without cross-flow; and, finally, interaction phenomena occurring under the impact of multiple droplets.

ANALYSIS OF THE COMBUSTION BEHAVIOUR PROCESS OF WOODY AND NON-WOODY BIOMASS

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Keywords: Woody and non-woody biomass, combustion process, experiments and modelling.

Abstract.
The combustion behaviour of biomass depends on its chemical and physical characteristics and on the furnace operating conditions, namely temperature, heating rates and atmosphere. If coal combustion process is well-known, there is the need to improve knowledge regarding the combustion of biomass. Biomass heterogeneity makes this knowledge process extensive and requires several experimental tests, using different facilities, biomass and operating conditions. In addition, the is also the need to adapt coal combustion models to biomass or develop new ones. To face all these challenges, our research group has developed experimental and theoretical work, which is an added value since the models developed can be validated in the laboratory, and the results from the experiments can be used in the models.
The sustainability of the forest is currently a problem due to the intense use of wood biomass for energy purposes. If there is the need to reduce the consumption of wood biomass, it is also a priority to proceed with the CO2 emissions reduction. The use of non-woody biomass can be a solution, but its combustion can contribute to enhance problems in the operation of furnaces due to the increase of ash deposits, slagging and fouling effects and corrosion/erosion, due to the high levels of alkalis and chlorine in some of these biomass. To assess these issues, our research group performed various combustion experiments on a drop tube furnace for different biomass, namely non-woody biomass, to study parameters like burnout, gases emissions and temperature, particulate matter, ash deposits and fragmentation. The results obtained are not yet conclusive, but turn clear the need to improve the studies on the combustion of non-woody biomass, since, depending on the biomass characteristics, the impact on the combustion process can be very relevant or not relevant at all. Woody and non-woody biomass particle ignition behaviour was studied in a small drop tube furnace. The effect of the type of biomass, gas temperature, oxygen concentration and inorganic compounds contents, on the ignition process was analysed. The studies reveal that the critical diameter for the ignition mode transition depends on the type of biomass and the ignition delay time decrease with the increase of gas temperature.
Regarding the theoretical work developed, the biomass combustion process in the drop tube furnace was modelled and the impact of particles' size assessed.

EXPERIMENTAL STUDY OF SINGLE DROPLETS IMPINGING ON LIQUID FILMS WITH VARIOUS DEPTHS: JET A-1 MIXTURES

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Keywords: Droplet Impact, Experimental, Jet Fuel, Liquid Film, Splash.

Abstract.
The present work is focused on a single droplet impinging upon a liquid film of the same fluid. This particular study is a matter of interest for several research areas and has a wide variety of applications such as fuel injection in internal combustion engines and process involving spray paints, coatings and cooling. When a droplet impinges upon a liquid film distinct outcomes are possible.
The main objective of this work is to test and observe those outcomes and conclude the influence of the fuel properties (density, surface tension and viscosity), the droplet size, the impact velocity and the liquid film depth. One of the goals of this paper is to report the existence of splash, which is described as the physical separation of the fluid immediately from the impact zone. The splashing of droplets upon liquid films with different depths has been investigated experimentally by several authors.
An experimental facility was design and built to study the dynamic behavior of a single droplet impinging on a liquid film. One of the focus of this work is to test mixtures of Jet A-1 and HVO, hence four fluids were selected for this study: water, 100% Jet A-1 and two mixtures of Jet A-1 and HVO. To assure the accuracy of the calculations, the fuel properties were measured, in fact five specific fluids were tested: 100% Jet A-1, 75/25, 50/50, 25/75 mixtures of Jet A-1 with HVO and 100% HVO. However, only the first three fluids were used since civil aviation only accept mixtures with at least 50% Jet Fuel in volume.
The set up includes a high speed camera that was manually triggered with a specific exposure time. The impact site is illuminated by a led lamp through a diffusion glass to provide uniform back lighting. A syringe pump connected to the needle and operated from the computer release the droplets with a specific pumping rate. The impact surface is composed by a perplex container. Five needles were used with different inner diameters to yield five distinct droplet sizes for each fluid. Additionally, three impact heights were stablished to provide three velocities and Weber numbers for each needle.

DESIGN OF AN EXPERIMENTAL FACILITY TO STUDY THE BEHAVIOUR OF A SINGLE DROPLET IMPINGING ON DRY SURFACE

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Keywords: Biofuels, Aero Engines, Cross-flow, Impinging droplets.

Abstract.
In order to successfully adapt low emission aero-engines combustors to burn biofuels, it Environmental concerns and the increase of oil prices brought the necessity of pursuing new ways to obtain clean and efficient energy production. In order to achieve this task the BISI project aims to successfully adapt low emission aero engines combustors to burn biofuels. The biofuels were investigated based on the effect of thermophysical properties on atomization, and droplet evaporation, since these are two essential stages prior to combustion. This allows for an appropriate assessment of their use in aero-engines, piston engines and gas turbines. Although there are some limitations to this application, being the biggest one, the fact that the new blend as to be constituted of at least 50 % (in volume) of the convention jet fuel (JF), the challenge is to implement this biofuel in the aeronautical industry immediately.
After the selection of the biofuel (NEXBTL) and the injector design, the experimental characterization of droplet/spray impingement processes required a design and construction of an experimental facility which is constituted by a wind tunnel and a droplet generation used to produce a droplet impinging in an aluminum surface trough a cross-flow. The diameter of the droplet is restrict by different needle diameters so different cases can be study. The wind tunnel was construct to reach velocities of about 90 m/s in order to be possible, in future works, to study secondary atomization with high velocity cross-flow. The current stage of the work developed is to measure the size and velocity of droplets before impinging on the surface as well as the identification of impingement regimes in order to validate numerical models. Thus, four substances are used in this study, 100% JF; 75% JF and 25% NEXBTL; 50% JF and 50% NEXBTL and H2O. Being the characteristics of the four substances different tree velocities of cross-flow are chosen, 7m/s; 10m/s and 15 m/s.
Therefore, this work presents the current stage of the Biofuel Spray Impact in Aero-Engines (BiSI) inter-institutional LAETA project considering the application of biofuels in aero-engine.

ENERGY PLANNING FOR THE INCREASE OF RENEWABLE ENERGY SOURCES

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Keywords: Energy planning, smart energy systems, integration of renewable energy sources, polygeneration.

Abstract.
Climate change, security of energy supply and fossil fuels depletion are well-known issues that determine the need of finding pathways for sustainable energy production. These pathways include energy efficiency and renewable energy production. However, the worldwide current energy infrastructure was designed for conventional technologies, based on fossil fuels that have provided large and cheap energy storage. This flexibility of fossil fuels enables the production of energy whenever is required. On the other hand, fluctuating Renewable Energy Sources (RES) as wind and solar are not flexible. Their intermittent nature introduces barriers to their high penetration into the electricity supply system, like the struggle to match the demand with the supply. In addition, the current energy systems consist of very segregated energy divisions, where the supply chains for mobility, electricity, heating and cooling have very little interaction with one another, disabling the use of possible synergies, decreasing its efficiency. A smart energy system is defined as an approach in which smart electricity, thermal and gas grids are integrated to achieve an optimal solution for each individual sector as well as for the overall energy system. They are used to identify the least cost solutions of the integration of intermittent RES into current and future energy systems.
In this scope, several studies were carried out. An integrated approach to power and water supply systems' planning was applied to the Island of S. Vicente, in Cabo Verde, with the purpose of increasing the integration of intermittent RES and minimizing the power and water production costs. In another study, the power supply systems of the Islands of Pico and of Faial were modelled and their interconnection was considered in order to increase RES penetration while decreasing the energy costs.
In addition, the natural gas Trigeneration Plant Climaespaço, located in Parque das Nações in Lisboa, was focused in various studies. This plant is used to supply heating and cooling to the buildings located in this area and produces also power for own consumption, being the excess sold to the national grid. A novel polygeneration system, based on the gasification of refused derived fuels, able to produce different assortments of sub-products (char; char and syngas; char and synthetic natural gas; and char, syngas and synthetic natural gas) was evaluated from energy and economic perspectives. In another study, the potential of the use of biomass in this plant was assessed. A technical and financial analysis was carried out regarding the replacement of natural gas by syngas, produced from the gasification of biomass.

MORPHOLOGY OF MULTIPLE DROP IMPACTS AND IMPLICATIONS FOR SPRAY-WALL INTERACTION MODELS

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Keywords: Multiple Drop Impacts, Spray, Phenomenology, Visualization

Abstract.
Spray-wall impingement models used to predict the outcome regarding liquid deposition, or secondary atomization, seldom consider the effects of the hydrodynamics associated with the interaction of multiple drops impacts in the vicinity of each other.
These interaction phenomena are random, and an adequate phenomenology is still lacking. Therefore, the purpose of the work presented is to perform an experimental study of the interaction phenomena occurring under the impact of multiple drops. Experiments consider the randomness of these events accounted by the impact frequency and distance between drops, and the effect of a pre-existing liquid film.
The analysis includes a phenomenological interpretation of the hydrodynamic events captured by high-speed visualization, statistical quantification of similar occurrences, and in the cases where secondary atomization occurs, the quantification of the dynamic characteristics of secondary droplets. Finally, we assess the applicability of existing empirical correlations for predicting the outcome of multiple drop impact.

A MULTI-SCALE APPROACH FOR MODELING HETEROGENEOUS REACTIONS IN POROUS CATALYSTS

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Keywords: Multi-scale modeling, porous catalysts, diffusion and reaction, intraporous diffusion limitations, CO oxidation, CH_4 catalytic partial oxidation.

Abstract.
Heterogeneously-catalyzed reactions in porous structures comprise different sets of chemical and physical (transport) mechanisms at different length-scale levels. The full-scale reactor modeling description for these reactions has been traditionally based on a pseudo-homogeneous (continuum) approach for the catalyst layer performance taking into account effective transport (and chemical) parameters estimated from old-fashioned theoretical models. Even though this kind of modeling approach is promptly applied – requiring a minimal set of geometrical properties to characterize the structure – and highly convenient for decreasing the overall simulation execution time, it neglects fundamental details related with the morphology and topology of the catalyst porous structure and ensuing transport regimes.
The current work presents a methodology for modeling heterogeneous reactions in porous catalysts at different length-scale levels. This methodology represents a step-forward in the computational evaluation of the species behavior within the complex pore network of supported catalysts, replacing the application of unsuited models. The methodology is based on the full simulation of the physico-chemical phenomena taking place at each relevant length-scale level of the reactor considering the detailed geometrical representation for the catalyst porous structure. The reactor performance at each length-scale level is evaluated according to a hierarchical bottom-up approach, in such a way that the performance at a lower length-scale level is firstly addressed and, consequently, transported to the next (upper) length-scale level.
The application of the current methodology is demonstrated for two different catalytic reactions with a strong importance in the energy and environmental protection sector: (1) carbon monoxide oxidation – for pollution abatement from automobiles (performed at catalytic converters) – and, (2) methane partial oxidation – for synthesis gas production, and consequently, for hydrogen generation or liquid fuels synthesis. Different noble metals and (bidisperse) porous structures are considered for each case. The role of the catalyst loading/dispersion and internal pore structure is evaluated for both reactions under typical operating conditions. Under inert (unreactive) conditions, the methodology results support a closer agreement with experiments than the results computed through widely applied transport models. At reactive conditions, a significantly different behavior is predicted considering the current multi-scale methodology and the classical continuum approach for the catalyst layer performance.

ABSTRACTS OF THE TOPIC

AERONAUTICS AND AEROSPACE

STRUCTURAL ANALYSIS AND OPTIMIZATION OF WING RIBS OBTAINED BY ADDITIVE MANUFACTURING

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Keywords: Topology Optimization, Wing Rib, Additive Manufacturing.

Abstract.
Additive manufacturing (AM) has emerged over the last years has a key technology in aircraft structural components' manufacturing. It enables more complex and more efficient structural topologies to be explored as well as to reduce material waste.
The present work aims at investigating stiffness and strength characteristics of several wing ribs having different prescribed or optimized structural topologies that were built by AM. This paper describes the design, the numerical and experimental procedures and the optimization of wing ribs manufactured with polylactic acid (PLA) using the Fused Deposition Modeling (FDM) technology.
The studied wing rib concepts were designed based on some traditional configurations where bending loads and shear loads must be transmitted along the rib to the wing spar. These wing rib layouts include two-dimensional truss, honeycomb and lightening-hole topologies, among others.
Numerical analyses were performed using Ansys Workbench's static structural analysis for two distinct loading cases. The first loading is a simplification in which the chordwise distributed force, resulting from wing lift, is replaced by two equivalent concentrated loads at the leading and trailing edges. The objective here is to numerically analyze a situation whose experimental validation is feasible. The second loading represents a more realistic situation where distributed loads are applied on the upper and on the lower surfaces of the airfoil to produce an improved structural response during flight.
A merit function containing maximum equivalent von-Mises stress, maximum displacement and strain energy is computed in order to quantitatively evaluate which wing rib concepts present the best overall structural performance. In addition, a structural optimization problem is performed using Topology Optimization (TO). This mathematical method, which optimizes material layout within a given design space for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system, is applied to minimize the wing rib mass subject to strength and stiffness constraints.
The results show a general good agreement between the displacements and stresses numerically calculated and the results obtained from experimental tests. Topology optimization is useful to produce structurally improved wing ribs with complex non-trivial layouts which are easily obtained by AM techniques.

OPERATIONAL SAFETY SYSTEMS FOR SMALL DRONES

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Keywords: Unmanned Aerial Vehicle, Flight Energy Management, Mission Planning, Obstacle Detection and Avoidance.

Abstract.
Recent incidents involving small drones have been raising concerns about their safe operation. It is foreseen that embedded safety systems will become mandatory in the near future, when stricter operational regulations will be put into place.
This work is part of the on-going research aimed to address the current lack of intrinsic safety systems by developing three distinct but highly coupled subsystems: flight energy management (FEM), obstacle detection (OD) and mission planning (MP).
The FEM is able to estimate the energy balance of the updated mission plan by making an assessment of the available energy, both stored and to be harvested in-flight (e.g., photovoltaic), and comparing it to the required energy, taking into account the aircraft performance and in-route weather conditions (e.g., wind and solar radiation). This energy balance is continuously updated in real-time.
The OD addresses all aspects of obstacle detection, namely the identification of the required aircraft instrumentation and the respective measurements processing to assess if there is probability of collision. Preliminary work using a LIDAR shows this sensor is valid for detecting close range obstacles. Further work will include its integration with other visual information in order to increase the detection range.
Lastly, the MP allows for both pre-flight mission planning as well as in-flight mission replanning, taking into account the data received from the FEM to attest the mission feasibility, and from the OD regarding the detection of new obstacles. The mission planning depends on a set of desired waypoints, a list of known obstacles (static, such as terrain and buildings, or dynamic, such as other aircraft), the vehicle performance capabilities and the rules of air, resulting in a well-defined reference path. This path can currently be optimized for different metrics, such as time (minimum for fast execution or maximum for extended endurance), distance (maximum for extended range) or energy (minimum for extended range).
These three subsystems are meant to be integrated into the drone flight-controller to provide valuable data to the operator and, as a last resort, to automatically take action to avoid collisions or abort energy limited missions.
A solar powered unmanned fixed wing aircraft, previously designed and built, will serve as one of the flight platforms to assess the operational capabilities of the developed safety subsystems. This vehicle has been flight tested to characterize its power requirements across the flight envelope thus providing key data used in the implemented algorithms' simulations.

ANALYSIS OF BENDING COMPOSITE LAMINATES USING DIFFERENT PLATE THEORIES: A MESHLESS APPROACH

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Keywords: Meshless methods, radial point interpolators, composite plates, high-order shear deformation theory, layerwise theory.

Abstract.

In the engineering field, the Finite Element Method (FEM) has settled has the most used and reliable numerical technique and, nowadays, the available commercial packages used for structural analysis predominantly runs this numerical tool. Nevertheless, there are also discrete advanced numerical techniques – such as meshless approaches [1] - that can handle the same problems as the FEM and, in some cases, can be even more efficient. This work makes use of two radial point interpolator meshless methods, which only need an unstructured nodal distribution discretizing the problem domain. These two numerical techniques were combined with the bending analysis of composite laminates plates using different displacement fields ruling the solid domain. In this study are analysed equivalent single layer theories following seven distinct high-order shear deformation theories (HSDTs) and also a layerwise theory. In the end, several composite laminates (symmetric cross-ply, antisymmetric cross-ply and angle-ply laminates) are analysed and the meshless solutions are compared with the available analytical solutions.

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BLENDED CUBIC SPLINE BASED NONLINEAR TRAJECTORY OPTIMIZATION

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Keywords: Trajectory Optimization, 4D Waypoints Navigation, Blended Spline parameterization, Nonlinear programming.

Abstract.

Trajectory optimization is a vital area in aeronautic industry. This technique enables generating optimal trajectories for vehicles with consideration of fuel consumption, travel time, obstacle avoidance, and many other requirements. However, there is no best method to solve the trajectory optimization problem but some methods might do a better job on specific problems. Some of the most common methods to solve trajectory optimization problems are collocation, Pseudo-spectral and Iterative dynamic programming methods. Although these methods can obtain solutions with high accuracy still some of these methods demand computationally intensive iterative numerical procedures and some approximate the controls by higher order polynomials, which give rise to excessive wavy curves for the states.

This paper deals with spline approximation method for solving trajectory optimization problem along 4D waypoints using direct optimal control approach. The state vector, its time derivative and the control vector are parameterized using cubic polynomial. Consequently, the objective function and constraints are expressed as functions of the value of state and control at the temporal nodes, this representation transforms the trajectory optimization problem into parameter optimization problem which is solved by nonlinear programming.

The proposed method is successfully applied to the generation of a minimum length optimal trajectory. The results suggested that the method not only requires less computation space and time but also generates smooth optimal trajectory with very accurate results. In this study two spline interpolation approaches have been considered, they are the natural cubic spline and the blended interlaced cubic spline. Both spline interpolation approaches have been used to generate trajectories between each pair of waypoints and finally compared with the optimal trajectory.

NONLINEAR FILTERING OF STOCHASTIC SYSTEMS WITH GAUSSIAN UNCERTAINTIES

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Keywords: Nonlinear state estimation, Kalman filter, Nonlinear filtering, Stochastic processes.

Abstract.

The problem of nonlinear state estimation is a crucial task and deserves a special attention particularly when it comes to time-critical applications in a highly nonlinear environment. The performance of the estimation is particularly dependent on the accuracy of the models and the availability of highly accurate information, however real-world physical systems might have parameters whose values can be known only approximately. The underlying uncertainties must also be considered since they might be crucial to evaluate the behaviour exhibited by the system and its estimate. A well-known method for dealing with such a task is the Kalman filter algorithm, mostly the extended Kalman filter. From the Kalman filtering framework, several new approaches have been developed, where various modifications are employed to provide a better convergence or to improve other performance characteristics. Due to the need of intensive calculations, most of these methods are inappropriate for time-critical applications.

The current nonlinear filtering methods are based either on the local linearization or on the statistical approximation of the nonlinear system. The present paper provides a comprehensive outline of the main nonlinear filtering methods (extended, unscented, cubature and particle Kalman filters) in a Gaussian environment, and several potential solutions are suggested to improve the performance of each method without compromising its advantages. Finally, some of the proposed solutions are successfully applied on the filter whose performance is compared with the classical extended Kalman filter. In this study, a realistic simulation of target radar tracking in a proportional navigation framework was considered, where the results suggested that the improved filter is capable of tracking the state vector with better accuracy.

PRESSURE DISTRIBUTION ON A POWERED LIFT F35-B AIRCRAFT IN GROUND EFFECT

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Keywords: Pressure Distribution, Ground Vortex, VSTOL, Impingement Jets.

Abstract.

The complex flow field generated by the impact of twin impinging jets in tandem through a low velocity crossflow was numerically studied to represent aerodynamically the powered lift of the F35-B aircraft when it operates close to the ground. Numerical simulation is presented for twin turbulent circular impingement jets on a flat surface perpendicular to the geometrical jet nozzle axis with the crossflow presence. The Reynolds number based on the jet exit conditions was 43,000, the jet-to-crossflow velocity ratio from 15 to 33.7, an inter-jet spacing of S=6D, and an impingement height of 3D. The mathematical model used is based on the solution of the continuity and momentum equations. A RANS formulation was adopted with the "k-ε" turbulent model to represent the turbulent stresses. High level of numerical accuracy was obtained by grid refinement and the use of the high order method QUICK. Furthermore, it is presented the pressure measurement next to the ground and the predicted mean vertical velocity component distribution along the vertical plane of symmetry. The results obtained for pressure distribution on the bottom of the fuselage and wings show the existence of regions where negative and null pressures are predominant. Near the impingement zone there are large negative pressure coefficients, that are responsible for the suckdown effect. On the impingement jets location, we can see the regions with high static pressure and the low pressures which are associated with the core of the ground vortexes. We can observe the formation of a ground vortex in the region between the impingement jets, a fact that has not been reported in the literature and which is surprising at the first sight, because the expected was to find an upwash fountain flow for this impingement height. Comparing the shapes of the negative pressure regions with the ground vortex we can verify that they are very similar, with the crossflow wrapping around the impinging point like a scarf.

A NEW RBRDO APPROACH WITH EXCLUSIVE USE OF GENETIC ALGORITHMS: APPLICATION TO COMPOSITE LAMINATE STRUCTURES

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Keywords: Uncertainty, Reliability-based Robust Design Optimization, Multi-objective Optimization, Composite structures.

Abstract.
A new approach to solve the demanding multi-objective Reliability-based Robust Design Optimization (RBRDO) problem of ply-angle composite laminate shell structures is developed. The key concept of this methodology is the exclusive use of Genetic Algorithms (GA) to execute both Robust Design Optimization and Reliability Assessment, to guarantee higher levels of accuracy throughout the optimization procedure. This way, it is possible to avoid the problem of premature convergence in local minima, commonly seen in gradient methods. Design optimization is considered as the bi-objective minimization problem of the weight (optimality) and the determinant of the variance-covariance matrix (robustness). The process is conducted by the Bi-level Dominance Multi-Objective GA. Reliability assessment is made by the Performance Measure Approach (PMA), as an inner-cycle of the design optimization, and is executed by a micro-GA (mGA). To make this process more efficient, the standard PMA is mathematically reformulated in directional coordinates and is transformed into an unconstrained maximization problem, such that the search space is significantly reduced to the surface of the hypersphere of radius β^a, and the search variables become the cosine directors, with an imposed norm equal to the target reliability index, β^a. The mGA works as an independent elitist GA, with reduced population, has the ability to control the dimension of the search space and only evaluates newly generated solutions. Throughout all the RBRDO, derivatives are analytically estimated by the Adjoint Variable Method, avoiding less exact estimations and exhaustive function evaluations by the Finite Differences Method. The limit-state functions are calculated by the Finite Elements Method. Lastly, to skip unnecessary runs of the PMA inner-cycle, for predictability unreliable design solutions, a binary reliability constraint is defined, in the RBRDO problem.

EQUILIBRIA OF A GYROSTAT SATELLITE WHEN THE GYROSTATIC MOMENT VECTOR IS PARALLEL TO THE SATELLITE PRINCIPAL CENTRAL PLAINS OF INERTIA

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Keywords: Gyrostat, Satellite, Equilibria.

Abstract.
The attitude control of a modern satellite is a crucial condition for its operation. In this work, is study the general case of equilibria of an asymmetrical inertial distribution gyrostat satellite, subjected to gravitational torque, moving along a circular orbit in a central Newtonian gravitational field. To solve this problem, other authors proposed a symbolic-numerical method, for determining all equilibrium orientations of an asymmetrical gyrostat satellite in the orbital coordinate system with given gyrostatic torque and given principal central moments of inertia. The conditions of equilibria were obtained depending on four dimensionless system parameters. The evolution of the domains in the study of equilibria was carried out in great detail, and all bifurcation values of parameters at which there was a change of numbers of equilibrium orientations were determined with great accuracy. In the present study is developed the complete set of analytical equations describing the evolution of the different bifurcation of equilibria, and is also achieved an accurate analytical expressions for the evolution of small equilibria regions near an axisymmetric configuration.
In the present paper is obtained in great detail, near the axisymmetric configuration, where $H_1=0$, and H_2 and H_3 different from zero, the evolution which confirm the existence on the general case of equilibria of the small equilibria regions near the axisymmetric configuration.
The knowledge and understanding of this new case study will permit a deeper understanding which will permit to optimize the design and operation of future spacecraft's.

PHILOSOPHY AND ETHICS OF AEROSPACE ENGINEERING: A WIDER VIEW

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Keywords: Philosophy of Engineering.

Abstract.
Engineering and Philosophy are typically conceived as two mutually exclusive domains. The perspective of some engineers and philosophers is even worse. Engineering is commonly divided into a number of different branches, and the same situation occurs with Philosophy. Representatives of these areas, especially ethics and aesthetics, seem to have mounted canons on their areas of the philosophy island in order to fire away at selected domains of the engineering world". Some philosophers as even gone so far as to claim that all main ethic and aesthetic failures of the 20th century are due to an engineering attitude that reduces nature to resources. And, others assert that technology constitutes a threat for human dignity.
According to the classic definition that engineers give of their own profession, engineering is "the application of scientific principles to the optimal conversion of natural resources into structures, machines, products, systems and processes for the benefit of humankind". Then, the philosophical attack could be replaced by "Engineering is the scientific art by which a particular group of human beings destroys nature and pollutes the world in ways that are useless or harmful to human life".
As they have become aware of such attacks (some) engineers have become involved in the study of philosophy to be better prepared to defend themselves. However, this problem is not yet fully understood and there are no recognized engineer philosopher schools. Surprisingly, even some Liberal Arts schools (where Philosophy is also taught together with many others disciplines in a multidisciplinary context) tend to hamper the inclusion of engineering. Ernst Kapp (1808-1896) was the first person to be considered an engineer philosopher, and developed a view of technology as a complex extension or projection of human faculties or activities. Then the most nuclear contributor to the engineering philosophy is Friedrich Dessauer (1881-1963) with the idea that the first element in the creation of a technical object is the presence of human purpose. But this should not be identified either with individual or social needs. The absence of advanced technology in the prehistoric world demonstrates that individual needs alone will not produce it. With (Mitcham, 1994) a broader approach to the philosophy of technology emerged that is concerned with the technology itself and that aims to understand both the practice of designing and creating artefacts (including artificial processes and systems) and the nature of thing so created.
In the present paper the focus is confined to the area of Aerospace Engineering. The inherent complexity and practical efficacy of this field call forth diverse kinds of thinking – scientific and technical, of course, but also economic, psychological, political, and so forth.

Experimental Research Of Forces During Take-Off of Birds

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Keywords: Biomimetics, Micro-Air Vehicles (MAVs), Nano-Air Vehicles (NAVs).

Abstract.
Humankind has looked to living organisms in search for answers to solve problems throughout their own existence. The term biomimetic derive from Ancient Greek and (bios ⇒ life; mimesis ⇒ imitation); biomimetic ⇒ life imitation, and has given rise to new technologies inspired by biological solutions at macro and nanoscales.
In its fullness meaning, biomimetic refers to all human-made processes, substances, devices, or systems that imitate nature; i.e., refers to the imitation of the models, systems, and elements of nature with the purpose of solving complex human problems. Biomimetic studies belong to a highly multidisciplinary area, encapsulating several branches of science: chemistry, physics, computers, textile, mathematics and electronics. One of the early examples of biomimetic reported the study of birds in order to enable human flight. Although never successful in creating a "flying machine", Leonardo da Vinci (1452–1519) was a keen observer of the anatomy and flight of birds, and made numerous notes and sketches on his observations as well as sketches of "flying machines". The Wright Brothers, who succeeded in flying the first heavier-than-air aircraft in 1903, derived inspiration from observations of pigeons in flight.
The increasing interest on Unmanned Air Vehicles (UAV's) and their several utilities blended with the needs of easy carrying and also stealth, lead to another requirement: to create the concept of Micro Air Vehicles (MAV's) and the Nano Air Vehicles (NAV's). Due to the current interest and the present lack of knowledge on the insect's and bird's flight, this study was intended to interpret the forces involved on the moment of the take-off of a bird, recurring to an experiment involving a fast data acquisition force sensor and high speed camera. The results reveal that the animal loses all the contact with the ground without any lift production of the wing downstroke, suggesting that he practically started the flight by jumping in to the air. Bird takes advantage of bending legs angle variation along take-off maneuver in order to maximize initial leg thrust. During the maneuvers performed to better assist its take-off, the bird complemented its thrust with the help of moving its center of mass forward by extending the neck forward and moving the head down and then keep extending the neck forward and moving the head up. The measured vertical take-off force was found to be quite significant reaching a value nearly 4 times the total weight of the bird. This result obtained by direct measurement with the force sensor is in agreement with the result obtained from the imaging data confirming the hypothesis that the bird practically started the flight by jumping into the air from a standing position.

A PORTUGUESE CONTRIBUTION ON EARLY AERIAL NAVIGATION

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Keywords: Early Transatlantic Flights, Air Navigation Systems, Precision Sextant.

Abstract.
Just 10 years after the Wright Brothers achieved the first heavier-than-air powered 12 seconds flight covering 120 feet, the British Daily Mail Newspaper (1913) put up a prize for the First Non-Stop Crossing of the Atlantic Ocean. The prize was suspended during World War I and renewed in 1918. Throughout 1914-1918, enormous advances in aviation technology were achieved - the fragile machine of 1914, had no resemblance when compared to the powerful, robust and reliable aircraft of 1918. However, despite the aircraft's evolution, the air navigation purpose of geographical positioning was still exclusively achieved by the use of maps and by ground visualization - with the identification of geographical reference points. Chronologically, the first transatlantic flight (multiple stages) was performed by a team of U. S. Navy, in a 6 stops flight strategy: began at May 8, 1919 (Rockaway Beach, New York) and ended on May 31 (Plymouth, England). This flight was performed exclusively with external means of navigation: radiogoniometry and with a line of 60 U. S. Navy destroyers, clicking advice and brandishing stiff antennae of light. On 18-19 May, Harry Hawker and Mackenzie Grieve attempted a non-stop flight Newfoundland in a Sopwith Atlantic fuel overloaded biplane. Overheating engine's problems forced them to ditch in the Atlantic some 14.5 hours into the flight. Aerial navigation was supported by radio wireless and a common sextant (later, they reported 150 miles deviation course). On 14-15 June 1919, onboard a fuel overloaded aircraft, John Alcock and Arthur Brown performed the very first successful non-stop Atlantic Crossing flight from Newfoundland and flew to Clifden, Ireland, in a flight time of 16:28h. Aerial navigation was supported by external and internal means interactions: radio intercommunications (directional wireless); an ordinary marine type sextant and a Mercator transparent chart projection. On July 2, 1919, the R-34 took-off from East Fortune and after a flight of 108 hours the British Airship arrived at Mineola, New York, at July 6. The return journey to Pulham Airship Station took place from 10 to 13 July and took 75 hours. Aerial navigation included radio wireless operators (with a 1,000 miles radio range) as well as a wide store of internal means of navigation. On March 30, 1922, Gago Coutinho and Sacadura Cabral took-off from Lisbon, on an epic journey to Rio de Janeiro, where they arrived on June 17, an all-flight performed exclusively with internal means of navigation; their devices and methods of aerial navigation were considered a huge air navigation upgrade at the time.

AERODYNAMIC ANALYSIS OF A FLAPPING AIRFOIL

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Keywords: CFD, Flapping Airfoil, Dynamic Mesh, Pressure Distribution, NACA0012.

Abstract.
Micro Aerial Vehicles (MAVs) are considered indispensable for both civil and military applications and for this reason studies are being carried out to further optimize the flight in aerodynamic terms. Most of the advanced research projects elected MAVs as flying vehicles having no dimension larger than 15 cm that are small as common birds or even insects. These animals have evolved and used flapping-wing systems for thrust and lift production for millions of years. So, recently the development of micro air vehicles (MAVs) has stimulated additional interest on the understanding of their underlying aerodynamics which is a subject of fundamental interest.
This study presents two-dimensional numerical simulations of a flapping NACA 0012 airfoil that are being used to set-up a wind tunnel experimental rig. The results are also used for comparison with the results obtained using the novel method of Smoothed Particle Hydrodynamics (SPH). The present results were obtained for an aerodynamic chord of the airfoil of 0.10m, a wind speed of 2.48m/s, an oscillating frequency of 48.5Hz and a motion amplitude of 0.012m, corresponding to a Reynolds number of 17,000. The unsteady aerodynamic analysis of this study is analyzed by solving the equations of continuity and momentum. The whole simulation process was made with Fluent (Ansys 18.0), using the "k-ε" turbulent model, dynamic mesh techniques, higher order schemes, user defined functions (UDFs) and unique methods for the grid generation. Beyond that, the static pressure field, the velocity vector field and horizontal and vertical forces are then presented along the whole flow domain.
The results show that the oscillating motion of the airfoil, even with a translational movement only, generates vortices at the leading and trailing edge that are later released from the airfoil surface. The velocity vector fields exhibit anti-clockwise vortices which push the air backwards creating a jet that generates a propulsive force based on the Newton's third law of motion. Therefore, an inverted Von Kármán vortex street is shown in the simulation domain instead of the traditional one that is associated with high drag effects. The lift force, due to the airfoil geometry and incidence angle, oscillates between two symmetrical values and an interesting condition occurs when it reaches a maximum in absolute value, the propulsive force is also maximized.

NUMERICAL MODELLING OF A COOLING DROPLET USING A TWO PHASE FLOW APPROACH

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Keywords: Ice accretion, heat and mass transfer, supercooling, Ranz-Marshall relations, cooling droplets.

Abstract.
The present work aims to study the freezing of droplets and the ice formation in the several surfaces of an aircraft. These processes have gain increased importance in the aeronautical field, due to the impact that ice accretion has on standard operation of an aircraft. It is known that 12% of all aircraft flight accidents, which took place in adverse weather conditions between 1999 and 2000, occurred due to the icing phenomena. There were reported 730 accidents between 1998 and 2007, related with icing. If there is not any change both in the current rate of accidents and incidents and in the continued growth in air transportation, there will be more than 4500 air travel fatalities per year due to icing related accident, by 2025. In order to prevent the solidification of water droplets and the subsequent ice accretion on an airplane surface, several methods to avoid and to remove the ice are implemented in the present days. However those measures can evaporate impinging water droplets or melt the accreted ice, there is still the potential risk of runback ice forming further downstream due to a refreezing of the ice-water mixture on unprotected areas. Supercooled large droplets tend to have greater inertia and are able to impinge on aircraft surfaces far beyond the limits of the ice protection systems. Aircraft often fly under subfreezing temperatures, in which the water droplets can still be liquid, experiencing a supercooling stage. In a cold atmosphere, in order to cool airborne droplets, heat transfer can occur by three different mechanisms, namely: convective heat transfer, convective mass transfer and thermal radiation from the droplet surface. Droplets generally nucleate at the surface forming a frozen shell which propagates inwardly. The temperature transition of the droplet is solved by balancing the internal energy with the energy removed by heat transfer, mass transfer and thermal radiation. Several models can be used with the purpose of describing the droplet freezing process. One of these models is composed by four stages, which includes supercooling. To solve it is necessary to make use of the Ranz-Marshall relations. The goal of the present work is to simulate the cooling of a water droplet using a two phase flow approach. It is intended to study the interaction between the liquid-gas phases of the droplet and air surrounding it.

MODELLING OF TRANSCRITICAL NITROGEN JETS USING REAL FLUID EQUATION STATE

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Keywords: Critical Point, Favre Averaged Navier-Stokes, Real Fluid Equation of State, Soave-Redlich-Kwong equation and Peng-Robinson equation.

Abstract.
The importance of prevention of further climate changes and exhaustion of natural resources in our planet demands the reduction of emissions and fossil fuel consumption of combustion engines. In order to do so, operating pressure and temperature of such engines has been increasing, as it is a way of enhancing combustion efficiency. The increase of pressure and temperature leads to reaching and surpassing the thermodynamic critical point of fuels and oxidizers. Several authors have been investigating fluid behaviour at conditions around and above critical. They concluded that fluids suffer strong properties variations which decisively influence the processes of injection and combustion of fuels and oxidizers. Thus, in order to correctly model flows at those conditions, one must accommodate the vigorous properties changes by the inclusion of real-fluid thermodynamics. In the present work a Favre Averaged Navier-Stokes approach originally developed for the study of variable density gaseous jets was modified in order to include a real-fluid equation of state. This required also the development of a new procedure for temperature calculation based on the Favre Averaged Energy Equation. Strong variations of specific heat, thermal conductivity and viscosity at these conditions make the task of temperature calculation extremely changeling and difficulties are currently still being faced. The current approach distinguishes itself from other approaches that also make use of a real-fluid equation of state by the fact that uses the temperature to determine density instead of using the mixture fraction. Two different real-fluid equation of state were considered: the Soave-Redlich-Kwong equation and Peng-Robinson equation. Results exhibit the potential of the current approach when compared with the previous method in which the flow density was obtained through the calculation of mixture fraction.

A FLEXIBLE IMMERSED BOUNDARY METHOD WITH CONTINUITY CONSTRAINT INTERPOLATION FOR UNSTRUCTURED POLYHEDRAL GRIDS

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Keywords: Immersed Boundary Method (IBM), Moving Body Problems, Unstructured Polyhedral Grids, Spurious Force Oscillations, Continuity Constraint Least-Squares.

Abstract.
A new immersed boundary interpolation for discrete forcing methods is presented. The method decreases spurious oscillations in the pressure field and consequently in the body force calculations which are a common issue in several immersed boundary methods. The method applies a continuity constraint in the least-squares interpolation, and guarantees that adjacent interpolation polynomials are continuous between each other. This approach strictly enforces a divergence-free velocity in the reconstruction domain, reducing time discontinuities caused by the boundary conditions applied at the immersed boundary.
Due to its flexibility, the method can be applied for any arbitrary unstructured grid. Several tests are carried out to validate the technique with different grid types: polyhedral, triangular and Cartesian. The method is shown to compute the correct velocity and pressure fields independently of the grid type. The effects of the cell topology in the spurious force oscillations (SFO) are also studied and the polyhedral grids are proven to be superior to their Cartesian and triangular counterparts.
Finally, some examples of moving bodies in a computational domain with complex static boundaries are provided. The new method allows the use of unstructured grids for the outer fixed boundary, which provides good geometry conformance and therefore good flow resolution in this type of problems.

NUMERICAL VERIFICATION OF ADJOINT-BASED SENSITIVITY ANALYSIS FOR MULTISTAGE TURBOMACHINERY DESIGN

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Keywords: Turbomachinery, discrete adjoint, multistage, gradient-based optimization, parallel processing, finite-differences.

Abstract.
With the exponential growth in computational power as well as improvements in the accuracy of computational fluid dynamics (CFD) tools, their use in turbomachinery design and analysis has seen a great increase, particularly in optimization environments, where gradient-based optimization algorithms are often selected for their efficiency. These algorithms require the computation of the sensitivities of the functions of interest to the design variables. The number of design variables in an optimization problem may be in the order of thousands. As such, the use of the adjoint approach for calculating the gradients is highly advantageous as it produces function sensitivities with computational cost that is nearly independent of the number of design variables. In the analysis of turbomachinery, accounting for the interaction between the multiple blade passages is of paramount importance if one wishes to increase the accuracy of the simulation. Many computational methods exist to address this interactions. The mixing-plane treatment is one of the most widely used methods in the steady analysis of multiple rows of a turbomachine. This paper describes improvements to a discrete adjoint solver of a proprietary CFD solver for multistage turbomachinery applications, namely the adjoint counterpart of the mixing-plane formulation of the direct solver. The adjoint solver is developed using the ADjoint approach, where the partial derivatives required for the assembly of the adjoint system of equations are obtained using automatic differentiation tools. A verification of the implementation of the mixing-plane against the finite-difference approximations is presented. Sensitivities of selected surface functions of interest, such as mass flow, to other selected design parameters, such as surface nodes or inflow boundary conditions, calculated with both methods are presented. The results show good agreement of both derivatives and emphasise the benefits of the adjoint approach versus finite-differences in terms of accuracy and computational cost.

ABSTRACTS OF THE TOPIC

ADVANCED MANUFACTURING AND ADVANCED MATERIALS

ON SIZE EFFECTS IN LOW-ALLOYED ALUMINUM

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Keywords: Flow stress, Metallurgical grain, Scale effects, Aluminum.

Abstract.
This paper presents a study on the influence of microstructural constraints (e.g. grain boundaries) and dimensional constraints (e.g. specimen size) on the flow stress of AA1085 and AA1050. Size effect is mainly introduced by the regulation of the metallurgical grain size (from 500 to 50 μm) and by decreasing of the specimen size (from 6 to 0.5 mm). Constitutive modelling was based on usual models which are readily available in most of the commercial codes. As a preliminary result, comparison of different stress-strain curves has shown that size effects can play a predominant role in the mechanical properties of materials.

ON STRAIN-RATE EFFECTS IN PURE METALS

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Keywords: Flow stress, Material hardness, Strain rate.

Abstract.
This paper presents a study on the influence of strain rate on the flow stress of several materials. The materials considered are six polycrystalline metals: Tin 99.999% and Zinc 99.999%, Aluminum 99.999%, AA1085-O, AA1050-0 and OFCH copper. The experiments involve the use of a drop hammer impact testing machine to increase the imposed strain rate up to 3000 s-1. The constitutive modeling follows traditional models well suited for computations because it uses variables which are readily available in most of the applicable computer codes. The results include complete stress-strain curves and hardness-strain curve for deformation at high-strain rate. Hence, interpretation of both the flow stress and the material hardness offers a means for distinguishing between the effects of instantaneous rate sensitivity from those of rate dependence of the dislocation generation.

AN APPROACH TO CHARACTERIZE EFFECT OF PROCESS PARAMETERS ON THE FORMABILITY IN SINGLE POINT INCREMENTAL SHEET METAL FORMING

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Keywords: Fracture forming limit, Shear fracture forming limit, SPIF, Copper.

Abstract.

Single Point Incremental Forming (SPIF) can be considered as a rapid prototyping process. In this process, the sheet metal is rigidly clamped at the edges and a forming tool, having a small diameter relatively to the component size, is used to incremental deform the sheet metal into the desired shape. The formability limits in SPIF are found to be higher than the conventional forming techniques defined by the forming limit curve (FLC) and can be defined by using the Fracture forming limit (FFL) and Shear fracture forming limit (SFFL).

The formability limits are affected by process parameters such as feed rate, step down, forming tool type and diameter and lubrication. The effect of these parameters on the formability of copper sheet metal with 0.8 mm thickness, is studied. It was found that the tool and the step down has major effect on the forming limit, whereas feed rate has negligible effect. The lubrication has positive effect on improving the formability and the surface roughness.

MACHINE VISION CONTROL SYSTEM APPLIED IN VACUUM INFUSION PROCESSES

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Keywords: Composite Materials, Vacuum Infusion Process, Automatic Control.

Abstract.

The present work is part a wider research project whose objective is the development of automatic control methodologies using a machine vision system to be implemented in Vacuum Infusion Processes.

Vacuum Infusion Process (VIP) is a type of manufacturing processes for polymer-based composite parts, in which a thermoset resin is injected into fibrous preform placed into a mold cavity (rigid bottom mold + vacuum bag) and the cured part is subsequently demolded. VIP provides low capital cost and the capability of consolidating complex shapes compared to the hand-layup prepreg/autoclave. However, in its present form, VIP is still limited by long filling time, low production rate and relatively high void content for high performance composites.

Current Vacuum Infusion Processes are based on an open loop control structure, depending on the operator experience in defining the resin injection strategies and subsequent computational simulation to validate the defined set-up. Human supervision is only necessary to cope with the manufacturing equipment.

This work intends to study the introduction of closed loop control methodologies through the use of a classical controller (PI) and a computer vision system, in order to vary the pressure in a vacuum infusion process, to control the velocity of the resin flow front and consequently decrease the void content in the final structure, improving its mechanical properties.

The resulting closed-loop control strategy provides proper adjustments in real-time control for uncertainties in the mold filling characterizations and depends, essentially, from the joint action of the two systems implemented: resin tank pressure and flow front speed control systems.

ON THE EFFECT OF INJECTION PRESSURE LEVEL ON THE MACROSCALE PERMEABILITY SCATTER

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Keywords: Permeability, Uncertainty, Resin Transfer Molding.

Abstract.

One of the most difficult tasks in flow simulation of fibrous preforms is the reliable characterization of properties of the preform (permeability and porosity). The experimental difficulties and lack of a standard approach for permeability determination, has meant that permeability values determined by laboratories with differing set-ups have produced contradictory data. This fact has led to a number of permeability benchmark exercises worldwide, the latest of which has proposed a jointly developed common experimental method in order to foster data agreement. Nonetheless, even with these results, some issues still remain regarding our understanding of the fundamentals of variability and uncertainty behind permeability experiments.

Permeability of the preform structure is subject to potentially large uncertainties due to the heterogeneity of the preform and experiment errors. The experiment errors contribute to the variability in measured permeability values. Experiment errors are uncertainties in each individual experiment for permeability measurement, induced by the imperfection of the experimental set-up and data evaluation procedure.

This paper addresses experimentally issues of the relationship between the scatter of permeability components and injection pressure level in in-plane infiltrations of woven fabrics. Radial infiltration experiments of ten layers of a 2 by 2 twill woven glass fabric at four injection pressure levels (1, 3, 4 and 6 bar) with ten repeats are carried out. This paper analyses the sources of the uncertainties, quantifies the magnitude of the uncertainties by error propagation and characterizes statistical properties of permeability components. Injection pressure, resin viscosity and cavity thickness are identified to be significant uncertainty contributors to experiment errors of the statistics of permeability. Based on the first order Taylor expansion of uncertainty propagation, it is shown that injection pressure influences the range of variation in permeability values. In other words, as injection pressure increases, the influence of the other uncertainty contributors (viscosity and cavity thickness) on the scatter of permeability is reduced. This observation is confirmed by experiment and is shown that the higher the injection pressure, the lower the associated errors into the permeability estimation.

FAILURE PREDICTION USING DUCTILE DAMAGE MODELS IN SHEET METAL FORMING SIMULATION

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Keywords: Failure prediction, ductile damage, inverse analysis, numerical simulation, sheet metal forming.

Abstract.

During the sheet metal forming processes, failure of the component may occur, being a constant topic of research with the aim to analyze or predict such behaviour. In order to achieve such prediction, damage models can be use that take into account the degradation of the material during the stamping processes.

In this work, different ductile damage models were selected namely based on GTN, Johnson-Cook and Lemaitre models, as a complementary methodology to predict the fracture behaviour of components during deformation by using finite element analysis.

The main goal of this study is to analyze and evaluate the performance of ductile damage models in failure prediction and compare with experimental failure components obtained from a cross-shaped part and a deep drawing cylindrical cup.

All damage models in this study show similar trend and fracture location prediction, which is in accordance with experimental evidence.

Acknowledgments.

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ARTIFICIAL NEURAL NETWORKS APPLIED TO THE PRESS BRAKE AIR BENDING PROCESS

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Keywords: Sheet Metal Forming, Press Brake Bending, Air Bending, Artificial Neural Networks.

Abstract.

The capability of predicting the final geometry on a sheet metal bending process, as well as, springback amount is an important feature.

Press Brake bending is a sheet metal forming deformation process in which the geometric interpretation is simple, but the control of final geometry is complex due to the interaction of different variables, either from the process or from the geometry.

The main topic to be considered in this article is the development of a method capable of establishing the required punch displacement to obtain a given forming angle, in press brake air bending using an artificial neural network (ANN).

Developing an ANN solution involves a development phase, through which the ANN model parameters are adjusted using available data from finite element simulation of the forming process and a training phase where a well-defined mathematical function provides the desired solution.

A developed model has been used to obtain results from multiple tool geometries and sheet thicknesses. The results obtained show that ANN can provide a better approximation of the function relating the forming angle with the punch displacement. Validation of implemented models, methodologies and its results are also performed by comparison with experimental data.

Acknowledgments.

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CONSTITUTIVE MODELS IDENTIFICATION FOR ALSI9CU3 CAST ALLOY AIMING CUTTING SIMULATION SUPPORTED BY MECHANICAL TESTING

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Keywords: Metal cutting, Mechanical Testing, Material characterization, Aluminium cast alloy, FE simulation.

Abstract.

Playing an enormous role in the current manufacturing scenario, metal cutting simulation has been the subject of thorough research. Even though the design of new tools or the improvement of certain machining strategies highly benefits from the accurate estimation of cutting force, chip geometry, tool wear or even surface integrity, industrial practice highly relies on tawdry empirical data. The development of robust numerical models able to support the industrial decision-making process are thus needed and material characterization is of utmost importance. The identification of the material's flow stress and damage constitutive laws under metal cutting conditions is still regarded as a challenging topic due to the high temperature, strain and strain rates typical of machining operations.

The goal of this investigation focuses on the characterization of the cast aluminium alloy AlSi9Cu3. A wide range of experimental techniques is used to identify the material's behaviour, such as compression tests at room and high temperature, quasi-static and high speed incremental testing. Shear-punch and fracture tests varying the specimen thickness and ligament length are conducted for damage calibration. Experimental orthogonal cutting tests are led in order to quantify friction levels. The obtained experimental results from longitudinal turning tests allowed for the validation of the constitutive model that was implemented in the metal cutting simulation models and a reasonable match being found for a wide range of cutting parameters.

EXPERIMENTAL STUDY ON MACHINABILITY OF GYPSUM PLASTER WITH POTENTIAL APPLICATION IN HYBRID MANUFACTURING

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Keywords: Gypsum Plaster, Machining, Machining forces, Surface Finishing, Moisture content, Binder content.

Abstract.

The gypsum plaster moulds have been extensively used in ceramic industry, slip casting process, as well as in metal casting process. This kind of industries, with the innovation or customization, need to produce reduced series or even single parts, which leads to the large production of moulds. The recent advances in extrusion base additive manufacturing (AM), in large size applications, allows a new application for gypsum plaster in production of large size moulds, not only in these industries, but also as a low cost substitute of other materials, such polyurethane and epoxy resins.

However, AM presents some disadvantages concerning the surface quality of the parts produced. In this case, a hybrid-manufacturing concept, that combines additive manufacturing and subtractive manufacturing for finishing operations, in the same machine, is an interesting process to produce gypsum parts. An innovative application on the extrusion base of gypsum plaster has been explored and opens another unexplored field related to the machining of this material.

The focus of this work is the CNC milling study of β-hemihydrate plaster with and without binder (Polyvinyl Acetate), in order to stablish the influence of cutting speed, feed rate, depth of cut and humidity of gypsum blocks on cutting forces and the most important, surface integrity, namely surface roughness, and sharp edges.

The results of the experimental work allow the establishment of fundamental cutting parameters that will be used in the machining of patterns or moulds and the influence of binder in machinability parameters.

PREDICTION OF SIZE EFFECTS IN LAMINATED OPEN-HOLE PLATES USING ONLY THE YOUNG'S MODULUS, THE STRENGTH, AND THE R-CURVE OF THE 0° PLY

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Keywords: Fracture Mechanics, Size effects, Analytical modelling.

Abstract.

An analytical framework is proposed in the present work to predict the notched response of carbon fibre-reinforced composites using only the Young's modulus, the strength, and the R-curve of the 0° ply.

The proposed coupled framework relies on an invariant approach based on the recently proposed Trace theory and Master Ply concept to predict the elastic properties of multidirectional laminates using only the Young's modulus of the 0° ply. To simplify the laminate strength prediction, the concept of Omni Strain Failure Envelopes and the Unit Circle failure criterion are used. Omni Strain Failure Envelopes can be obtained superimposing the envelopes of the constituent plies for a given laminate. An inner envelope that covers all controlling plies will then define a material property that is independent of laminate lay-up configuration. To make laminate failure analysis simpler, the Last-Ply Failure Omni Strain Failure Envelope can be approximated by a Unit Circle using the uniaxial tensile and compressive strains-to-failure as normalising factors. Therefore, only the longitudinal tensile and compressive strengths of the 0° ply are needed to determine laminate ultimate failure. Finally, an analytical model based on Linear Elastic Fracture Mechanics and Laminated Plate Theory is used to estimate the fracture toughness of balanced laminates from that of a 0° ply, and using the ply and laminate elastic properties obtained from the Trace theory.

Using the predicted laminate unnotched strength and laminate mode I fracture toughness, the notched strength of general laminates can be calculated using a coupled stress and energy Finite Fracture Mechanics criterion. When compared with experimental results, a good correlation between the predictions of the proposed analytical framework and the notched strengths of quasi-isotropic carbon/epoxy laminates is obtained.

OPTIMIZATION OF HYBRID COMPOSITES IN UNIAXIAL TTRACTION INTRODUCING A PSEUDO-DUCTILE RESPONSE

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Keywords: Hybrid Composites, Pseudo-ductility, Analytical Modelling, Multi-objective Optimization, Genetic Algorithm.

Abstract.

Composite materials have met increased interest in the industry, especially in lightweight construction (for example, in automotive and aerospace applications) due to their unique properties compared to the more conventional structural materials. However, they are characterized by having a brittle failure, i.e., typically they have no ductility, which may limit their usage. A ductile failure of a composite material is desired, like in metallic materials, which present yielding after the elastic region followed by strength increasing. Hybridization is a key factor to introduce a so-called pseudo-ductile behavior in the fiber reinforced composite material. The hybridization here consists in the use of two different types of fibers (with different failure strains or strengths) embedded in a polymer matrix, with the goal of improving overall composite properties and performance. The present work analyzes and optimizes this hybrid fiber reinforced composite based on failure analytical models. Ultimately one discovers the optimal mix of fiber materials which produces an "optimal" ductile behavior in the composite material when it is subjected to a tensile load.

To predict the failure of composite materials, two different analytical models previously developed were coupled with optimization algorithms. The first model considers a bundle composed of two different types of fiber, without matrix, named as hybrid tows. To account for the presence of the matrix, a second analytical model is used, based on the multiple fiber fragmentations.

Despite the simplicity of these failure models, they are very useful to work on a correct parameterization of the response curve of the hybrid composite when subjected to uniaxial traction. A parameterization of that response is necessary for its control and consequent optimization to achieve the desired pseudo-ductile response. One proposes here four parameters which fully characterize the response. These parameters are included in the optimization problem. The problem is formulated here either as a multi-objective problem or as single objective one using a weighted sum of objective functions. The optimizations are performed using the Genetic Algorithm (GA). The final goal is to identify the optimal mix of the base constituents in the hybrid composite.

MATERIAL CHARACTERIZATION OF BUTT WELDED JOINTS IN A HIGH STRENGTH STEEL (CLASS 700 MPA)

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Keywords: Advanced Materials, High strength steel (class 700 MPa), Fatigue, DIC, Hardness, Yield strength, Microstructure.

Abstract.

Technology is improving daily and the need to manufacture new materials is increasing. Therefore, it is necessary to collect the maximum information, as possible from the new materials in order to comprehend the material´s limitations in several conditions. One of the many information which can be retrieved, is the behavior of the welded material when is subject to fatigue loadings.

The objective of this work is to evaluate the fatigue strength of a high strength steel (class 700 MPa) under stress ratio of R = 0.1 for a specific welding geometry and welding parameters by determining the Paris law for the evaluated case. A Digital Image Correlation method is used to determine the crack length evolution along the several fatigue cycles which the specimens were subjected. Another objective of this work is to assess the variation on hardness along the weld zone and heat affected zone and study the influence of the 4 different sets of welding parameters on the same propriety. Furthermore, the yield strength profiles are also determine for the different sets of welding parameters using a correlation which relates the Vickers hardness with the yield strength value. Finally, it is also study the steel microstructure in different zones, which appeared, due to the welding process and it is compared with the microstructure of the base material.

MICROSCALE ANALYSIS OF FIBRE HYBRID POLYMER COMPOSITES USING A MODIFIED SPRING ELEMENT MODEL

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Keywords: Polymer composites, Fracture, Numerical Modelling.

Abstract.

The need to understand the failure mechanisms in composite materials at the micro level

has gained additional importance due to the pressing need to develop high performance materials for more demanding applications. This understanding makes it possible to develop a new generation of polymer composite materials in-silico by recurring to e.g. hybridization, either fibre hybridization or ply hybridization.

To understand fibre dominated failure it is necessary to have accurate models that are able to capture the main failure mechanisms in this type of failure. Although complex micromechanical models that capture these mechanisms exist, they are computationally expensive and can only be used for a limited representative volume element size. Simplified models are, therefore, necessary to allow faster predictions, although at the cost of some accuracy. The faster computation times of simplified models allow also the study of more material variations and can be used for optimization purposes.

In this work, an extension of the Spring Element Model (SEM) to a random fibre packing and hybrid composites is presented. This model allows the study of the tensile failure of both hybrid and non-hybrid composites as well as study the fibre fracture and clustering phenomena that lead to the material failure. The numerical results obtained are directly compared to the experimental results available in the literature, both in terms of stress-strain behaviour and fibre breakage and cluster formation.

NUMERICAL STUDY OF FATIGUE CRACKS PROPAGATION IN BUTT WELDED JOINTS IN A HIGH STRENGTH STEEL (CLASS 700 MPA)

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Keywords: Stress intensity factors, Extended finite element method, Abaqus, Crack propagation, Fatigue crack growth.

Abstract.

Nowadays material characterization is an important task in manufacturing field. Therefore, numerical models are required to simulate the real mechanic material behaviour without wasting. The stress intensity factor (K) is an important parameter for estimating the life of the cracked structure. The main goal in this work is evaluate the fatigue strength of 4 high strength steel (class 700 MPa) samples with different welding configurations under stress ratios of R = 0.1 and R=0.5. In order to analyze the geometry effects on the fatigue strength, simulations were made using Abaqus Software in each sample. At first, the stress intensity factors, K, have been calculated on a static analysis using extended finite element method (XFEM) in Abaqus Software, the results were compared with the theoretical values. Then the fatigue crack growth was simulated using the XFEM in Abaqus software on a dynamic analysis, computing the different stress intensity factors for different crack lengths. The fatigue crack growth curve was made accordingly with the Paris Law with the crack length variation vs number of cycles. The best configuration in welding position was determined by the highest fatigue crack strength.

DAMAGE MODELLING OF CONVENTIONAL GRADE AND THIN-PLY NANO-REINFORCED COMPOSITE LAMINATES

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Keywords: Composite Laminates, Carbon Nanotubes, Finite Elements.

Abstract.

Composite laminates composed of conventional grade and thin-ply carbon fibre-epoxy plies nanostitched using vertically aligned carbon nanotube arrays have been recently developed. It has been shown that this innovative process guarantees a good dispersion of carbon nanotubes and improves both intralaminar composite strength and interlaminar toughness and significantly increases the electrical and thermal conductivity. To better understand the toughening effects of the inclusion of CNTs in the interfaces of carbon-epoxy laminates and as a complementary study to the work presented in refs. [1-3], virtual short beam tests on thin-ply and conventional grade baseline and nano-reinforced laminates are performed. Intralaminar damage is simulated using the continuum damage model developed to predict the onset and propagation of intralaminar damage mechanisms in laminated composites proposed by Maimí et al. [4] and interfacial damage is simulated using cohesive elements. The numerical results suggest that the nanostitched interfaces are 5-15% tougher than unreinforced interfaces depending on the material system.

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DAMAGE TOLERANT STRUCTURES UNDER MIXED MODE LOADING

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Keywords: Fatigue, biaxial fatigue, crack growth, mixed mode, XFEM.

Abstract.
A brief overview of the DalMat inter-institutional LAETA project is presented. Main objective was the study of structural integrity for mixed-mode situations. Through a case study suggested by AeroG, the FEUP team worked on the modelling of mixed mode crack propagation and results of that research led to a FEUP master thesis and several publications. At IST crack propagation under in plane biaxial conditions was studied for an aeronautical application of Mg alloy component and outcomes of that work also includes two master theses. Also fracture surface analysis was carried out regarding the influence of the different loading paths and stress ratios applied concerning fatigue life, crack initiation plane and fracture surface morphology. Further to a very concise presentation of the above work, the presentation will show the current work performed of which the paragraphs below give a summary.
Crack propagation under mixed mode loading is found in multiple structural components due to complex loading conditions and component geometry. With the development of new numerical approaches, several computational techniques are available to model effect of shear loads in the crack propagation. At FEUP some numerical tools available to assess the fatigue crack behavior under mode I (tension/compression) and mode II (in-plane shear) loading conditions were explored. One of the numerical techniques explored extensively in this project was the Extended Finite Element Method (XFEM) implemented in Abaqus. XFEM technique has great interest in fracture mechanics due to the capability to model with high precision discontinuities as cracks using enrichment functions and allowing to create and growth cracks within the elements. The results obtained with these tools were validated with experimental tests performed on aluminum alloy AA6082-T651 20 mm thick samples. Modified standard specimens as the compact tension specimen were machined with additional holes to create shear loading conditions in the crack tip. Additionally, three-point bending specimens were also used. In this case the loading conditions were not symmetric to promote shear in the crack tip. An extreme case of pure mode II was also experimentally evaluated using four-point bending.
Reasonable convergence between numerical and experimental results were found in most of the cases analyzed. However, some mesh sensitivity to the crack path and in the cases studied was found, with unstructured meshes showing better agreement compared to the experimental results.

ABSTRACTS OF THE TOPIC

BIOMECHANICS

NUMERICAL MODELLING OF THE HUMAN COCHLEA AND ASSOCIATED PATHOLOGIES

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Keywords: Inner ear, cochlea, hair cells, hearing.

Abstract.

The hair cells located in the inner ear are responsible for the transduction of the mechanical energy into electrical energy. These cells are present along the cochlea and respond to different sound frequencies in line with its position in the spiral.

Our ears are subject daily to several noises which can permanently damage it. Diseases such as the Ménière disease, can affect the inner ear eliminating or reducing the hearing ability and compromise the oral communication. The clinical manifestations of Ménière's disease including tinnitus and vertigo problems. Tinnitus is a sensation of ringing in the ears or head in the absence of an external physical sound source, and is often accompanied by hearing loss. Vertigo is a sensation of dizziness that results from disease processes that affect the vestibular system. The presbycusis, known as age-related hearing loss is a sensorineural disorder caused by progressive and irreversible degeneration of the inner ear structures, usually this disorder affects the high frequencies of hearing.

The adult hair cell has no capacity of regeneration. For this reason, this topic become extremely important and relevant. Since the damage is permanent, the use of cochlear implants has been applied. These implants have shown to be a good solution able to bring the hearing again. Some problems related to this technique are the insertion of electrode arrays into the cochlea which can cause damage in the healthy cochlear structures, thus becomes important to improve the surgical procedure and optimize the material and design to be used in the implants.

A 3D finite element model will be performed with the propose of helping in the comprehension of the inner ear function. The several pathologies associated with the inner ear will be simulated and the results will allow to understand the influences of such pathologies in the normal hearing. The model will include the mechano-electrical transduction that takes place in the hair cells.

It is important to understand the mechanisms behind the human hearing, because it will allow a faster diagnosis, and potentially an effective treatment.

A CONTINUUM MODEL FOR THE MECHANICS OF ACTOMYOSIN NETWORKS

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Keywords: Continuum Mechanics, Actomyosin Networks, Contraction.

Abstract.

In the context of a mechanical approach to cell biology, there is a close relationship between cellular function and mechanical properties. In recent years, an increasing amount of attention has been given to the coupling between biochemical and mechanical signals by means of constitutive models. In particular, on the active contractility of the actin cytoskeleton. The actomyosin-mediated contractility mechanism generates mechanical stress and underlies muscle contraction, cell migration, cell division, and tissue morphogenesis.

Given the importance of the actin contraction on the physiological functions, this study proposes a constitutive model to describe how the filamentous network controls its mechanics actively at in vitro conditions. Embedded in a soft aggregate, the network behaves as a viscous mechanical continuum, comprised of isotropically distributed cross-linked actin filaments and actomyosin bundles.

Trough virtual rheometry experiments, the present model relates the dynamics of the myosin motors with the network stiffness, which is to a large extent governed by the time-scale of the applied deformations/forces and by the chemical environment.

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APPLICATION OF ANISOTROPIC VISCO-HYPERELASTIC CONSTITUTIVE MODELS FOR THE SIMULATION OF BIOLOGICAL TISSUES

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Keywords: Constitutive modelling, Viscoelasticity, Finite element method.

Abstract.

Computational bioengineering is experiencing major advances in the past decades, taking advantage of the latest, fast-developing computational capabilities. This method has become a valuable alternative to in-vivo assessment since it has no ethical constraints. Biological tissues are a complex material, presenting an anisotropic visco-hyperelastic behaviour. Highlighting viscoelasticity, it is known that this feature has an important functional significance. Tissues exhibiting a more pronounced creep behaviour will stretch more under a constant load, and tissues presenting a higher relaxation behaviour will show a higher decrease in the stresses over time, when held at a constant length. The present work focused on the implementation of a viscoelastic constitutive model suitable for finite element simulations involving soft tissues, using ABAQUS® software. A user-defined material subroutine UMAT prepared for anisotropic hyperelastic materials was previously developed by [1] and served as a basis for this work. Viscoelasticity was added to the developed UMAT through a recurrence update algorithm in the FORTRAN language. The constitutive model applied was the generalized Maxwell model, following the nomenclature of [2]. The final material subroutine UMAT can be applied to analyse different biological tissues if the material parameters are correctly calibrated for the tissue in study. Notwithstanding, the ultimate goal of this research was to study the pelvic floor tissue during a vaginal delivery, complementing the work developed by [3],[4].

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CHARACTERIZATION, SIMULATION AND OPTIMIZATION OF PROSTHESES AND ARTERIAL STENTS

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Keywords: Arteries, Biomechanics, Mechanical testing.

Abstract.

This work aims to characterize, simulate, and optimize arterial prostheses and stents already available in market. For that purpose, the arterial mechanics should be studied, to allow the proper simulation and optimization of prostheses.

The experimental protocol followed began with a literature review of the existing arterial stents and potential research gaps in this field. It was thus realized that bare metal stents are the type of arterial stents that are no longer used and have been replaced over the years. However, there are many factors that point to their potential to become (again) the gold standard for these medical devices.

To evaluate experimentally which characteristics of these devices can be improved, it was necessary to construct a prototype device able to:

-induce pressure variation inside the blood vessel

-acquire the 3D deformed state of the vessel + stent assembly

This will allow to understand the changes occurring to the vessel with/without the stent presence.

The prototype designed consists of a stepper motor, a pressure sensor, an Arduino and a structural support component. The operation of the prototype is controlled by the user, through an interface of easy use and understanding, which allows to vary the pressure inside the vessel to study.

As a follow-up step we have the characterization of vascular and arterial tissue, with the extraction of the stress-strain curves from the experimental results obtained; the samples' geometry and the determination of the mechanical properties.

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MIXED EFFECTS MODELS APPLIED TO UNIAXIAL TENSION DATA ON SOFT TISSUES

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Keywords: Nonlinear Mixed Effects (NLME) Models, Biomaterials, Mechanical testing, Nonlinear mechanical behavior.

Abstract.

Mixed effects models (MEM) have become popular to analyze longitudinal or repeated measurement data when the focus is to infer individual-specific characteristics from the population mean values (Davidian and Giltinan, 1998). This article discusses the results found using linear mixed-effects models to model the experimental data (uniaxial tension tests) in INEGI's database on biological soft tissues, more precisely vaginal tissue. It uses first stage linear models in the parameters such as Neo-Hookean or Money-Rivlin, that have shown to describe well the linear domain, while it tries to find a meaningful second stage model to relate the mechanical properties with etiologic characteristics of the population, such as age, body mass index, parity, and mode of delivery.

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A NEW BIOMECHANICAL MODEL OF BONE REMODELING COMBINED WITH ADVANCED DISCRETIZATION TECHNIQUES

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Keywords: Biomechanics, mathematical modeling, bone remodeling, microscale analysis.

Abstract.

This work presents a new approach developed to simulate the process of bone remodeling. During bone remodeling, bone tissue changes and adapts its internal trabecular structure according to several chemical and mechanical cues to which bone is sensitive to. This study proposes a novel mathematical model capable to reproduce this stimulation, describing the action of bone cells (osteoclasts and osteoblasts) and their impact on bone mass. So, from Komarova's model and the following extended version of Ayati and co-workers, a new mathematical formulation is created, having the following three main variables – cellular density of osteoclasts, cellular density of osteoblasts and bone mass. In order to recreate the variation of these variables both in space and in time three different numerical methods are applied - the Finite Element Method (FEM), the Radial Point Interpolation Method (RPIM) and the Natural Neighbour RPIM (NNRPIM). To perform the numerical tests, a two-dimensional bone patch is used as the numerical example. After applying a load, bone cells are able to respond according to the stimulus causing an adaptation of bone mass' spatial distribution. Thus, with these promising results, future work aims to reproduce pathologies related to bone remodelling and the effect of drugs used for treatment.

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MULTIVARIATE ANALYSIS FOR THE UNDERSTANDING OF THE FAILURE MECHANISM IN BREAST IMPLANTS

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Keywords: Breast Implants, rupture mechanisms, thickness, fatigue.

Abstract.
The controversy surrounding the Poly Implant Protheses (PIP) implants caused heightened anxiety and extensive publicity regarding implant safety. The main goal of this study was to find an explanation for the seemingly higher rates of rupture for PIP implants. An experimental protocol was developed to analyze twenty-two PIP explanted implants (eleven intact and eleven ruptured), ten PIP control and four the other Brand. Breast implants were obtained from woman at the Department of Plastic Surgery of Gaia Hospital Center, Portugal. All implants were studied by a combination of tensile test, chemical (Fourier transform infrared-FTIR) and surface analysis (Scanning electron microscopy–SEM). A total of 1726 samples were cut from the implants' shell to conduct this research. This study demonstrated that the physical characteristics of the PIP are variable, and have a strong relationship with the shell thickness. Ruptured explanted implants were thinner and weaker than intact explanted and control implants. Comparison of FTIR spectra of all implants did not demonstrated changes in material characteristics during the period of implantation. Analyzing the ruptures by SEM, striations were found, which normally appear due to fatigue phenomena. The thickness variation and fatigue phenomena were identified as the main reasons leading to implants failure. According with authors' understanding of the problem, these findings may be associated with the typical manufacturing process of implant shells. To better understand this type of failure and its relevance among other implant rupture mechanisms further research is required.

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A MULTISCALE HOMOGENIZATION METHODOLOGY MERGING THE FABRIC TENSOR CONCEPT AND A BONE PHENOMENOLOGICAL MATERIAL LAW

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Keywords: Meshless Methods, Fabric Tensor, Homogenization, Multiscale.

Abstract.

Bone can be classified as hierarchical structure, where the different structural levels can be identified from the microscale to macroscale. Multiscale models enable to define material properties using homogenization techniques. In this work is presented a new homogenization technique for trabecular bone tissue. This technique uses the fabric tensor concept and a bone phenomenological material law. This allow the homogenised material to be defined considering the trabecular bone principal direction but also is able to link the apparent density with the trabecular bone mechanical proprieties. This process is able to reduce the analysis computational costs by overcoming the need of trabecular highly heterogeneous medium geometries. The homogenization technique is combined with the natural neighbour radial point interpolation method (NNRPIM). In order to verify the efficiency of the technique several examples are solved using a confined square patch of trabecular bone under compression. At last are compared results obtained with a classic homogenization technique and the proposed methodology are compared.

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EFFICIENT MESHLESS TECHNIQUES FOR THE ANALYSIS OF COMPLEX STRUCTURAL AND BIOMECHANICAL PROBLEMS

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Keywords: Biomechanics, structural analysis, meshless methods, non-linear analysis.

Abstract.
It is possible to find in the literature several advanced discretization techniques capable to efficiently simulate the structural behaviour of inorganic and organic structures. Although the most popular discretization technique is still the finite element method, recently new advanced discretization techniques started to appear – the meshless methods. With meshless methods it is possible to obtain a discrete geometrical model directly from medical images or CAD software. Thus, this meshing advantage is a true asset in both computational mechanics and biomechanics. Indeed, the most attracting feature of meshless methods is their unique capability to discretize the problem domain with an unstructured nodal distribution. Distinct meshless approaches are well-described in the literature [1]. In this work, radial point interpolation meshless methods are used to analyse nonlinear structural and biomechanical problems, such as crack propagation, contact, free and forced vibration of sandwich structures, acoustic problems and the transient behaviour of bone tissue. The meshless results are compared with the finite element method solution, allowing to understand the efficiency and accuracy of meshless methods.

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THE FREE VIBRATION ANALYSIS OF THE CUPULA IN THE INNER EAR USING MESHLESS METHODS

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Keywords: Vestibular System, Biomechanics, Numerical Simulation.

Abstract.

The inner ear is the main responsible for the balance function in the human body. One of the main causes of vertigo symptoms is the abnormal concentration of otoconia particles around the cupula, which is the main sensory section of the inner ear. Thus, the determination of the natural frequency (first vibration mode) of the cupula will allow to stimulate it externally. The goal is using the resonance effect to disperse the otoconia from the cupula, reducing the vertigo symptoms.

In order to understand the dynamical response of the cupula, a 2D and 3D geometrical model of the cupula was constructed. Then, a free vibration analysis was performed using two distinct numerical techniques, such as the finite element method (FEM) and a radial point interpolation meshless method (RPIM). Meshless methods are advanced discretization techniques that allow to discretize the problem domain using only a cloud of points, allowing them to construct geometrical models directly from medical images. The results obtained with the cupular model show that RPIM is capable to provide results very similar with the FEM. However, the RPIM solution is smoother. On the other hand, the FEM computational cost is lower than the RPIM.

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NUMERICAL ANALYSIS OF CHITOSAN NERVE CONDUITS USING MESHLESS METHODS AND NEW PHENOMENOLOGICAL LAWS

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Keywords: Chitosan, meshless method, constitutive model, structural analysis.

Abstract.

Peripheral nerve injuries are a major cause of morbidity and life-long disabilities that represent 3% of all trauma patients worldwide. There are different strategies that can be implemented in order to repair a nerve gap. In one of these strategies, an artificial nerve conduit can be sutured between the nerve stumps without tension, creating in its lumen optimal conditions towards the regeneration of the peripheral nerve.

In order to show the non-linear elasto-plastic behavior of chitosan, it was elaborated a constitutive model, where both the yield criterion and the corresponding yield surface were considered. For this, some mechanical properties of chitosan were obtained from the literature, such as the Young's modulus, the yield stress and the strain for both compression and tension conditions.

Afterwards, the constitutive model was combined with discrete models of chitosan nerve conduits using numerical methods to analyze them such as the finite element method (FEM) and the radial point interpolation method (RPIM), which is a meshless method. Stress and displacement fields were obtained in order to comprehend the structural response of the nerve conduits when subjected to external forces. The discrete models had variable geometrical parameters, such as internal and external diameters, and length. The elastic constants considered were the Poisson's coefficient and the Young's modulus, which was obtained from studies in the literature referring to pure chitosan samples with varying degrees of deacetylation. This is an important property of chitosan since it influences its physical, chemical and biological properties such as the tensile strength.

Acknowledgments:

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STRAIN ANALYSIS IN THE DRILLING OF HUMAN AND BOVINE BONE

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Keywords: Bovine Bone, Human Cadaveric Tibiae, Drilling, Strain.

Abstract.

The growing importance of bone surgical drilling procedures has motivated the development of assessment methods aimed to prevent bone injury. Different studies on the parameters influencing bone drilling have been published. However, most of the results are based only in the analysis of temperatures. There is a lack of information on the mechanical damage on bone, especially about bone tissue surface integrity and the strain distribution during drilling. The challenge during drilling should not be limited to avoid thermal damage but also to predict the strains affecting the bone, since the cutting force and the accuracy of the osteotomy depends upon the surgeon's manual skills.

The present study was designed for the evaluation of strains generated during the cortical bone drilling, as function of different drilling parameters. An experimental approach has been conducted using ex-vivo bovine bones and human cadaveric tibiae. The bones were instrumented with linear strain gauges at flat surfaces of bone tissue during the drilling process. The drilling parameters selected for this study consist in the use of three different drill speeds (520, 900 and 1370 rpm). The feed-rate was not controlled, since in clinical practice this parameter varies from surgeon to surgeon. All holes were performed using a vertical machine with a twist drill bit with 4 mm of diameter and a point angle equal to 118º. The tests were conducted at room temperature (20-23º C) without applying cooling at drilling zone.

This study allowed the analysis and comparison of the strains generated during drilling of ex-vivo bovine bones and human cadaveric bones. All results show that the increase of drill speed leads to an increase of the strain during the drilling. It was noted that the strains tend to increase with tool penetration and, consequently, the osteotomy depth. The present results are consistent with our previous studies made using polyurethane foam materials with properties that are similar to the human cadaveric bone.

NUMERICAL SIMULATION OF STRESS AND STRAIN DISTRIBUTION IN SKIN WOUNDS: A PRELIMINARY STUDY

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Keywords: Skin, wounds, stress fields, strain fields, FEM, meshless methods.

Abstract.
Human skin is the largest human organ and an important physical barrier that allows body homeostasis. During wound healing, this mechanically flexible organ is capable to repair itself. Nevertheless, the wound represents an abrupt change in the skin continuum, leading to stress concentrations in surrounding wound area.
Advanced discretization techniques, such as the finite element method (FEM) or meshless methods, are suitable computational tools to simulate biomechanical problems.
Meshless methods allow to discretize the problem domain using only a set of nodes without any pre-established relations. The meshless methods used in this work construct the interpolation functions using the Radial Point Interpolators techniques, which combines radial basis functions with polynomial functions to obtain the approximation.
This study aim to construct a 2D model of skin wounds with different depths, using advanced discretization techniques, and to analyze the stress and strain fields obtained. Additionally, it is also aimed to simulate the suturing process and to analyze the stress and strain fields obtained. Being this a preliminary study, only small-strain elastic-static assumptions are considered. The typical geometry and mechanical properties of the several tissues involved in the simulation are obtained from the available literature.
In the end, the results from the FEM and meshless formulations are compared. The experience acquired with the development of this work permits to apprehend that meshless techniques possess the potential to represent the domain directly from medical image techniques, an advantage in tissue biomechanics.

Acknowledgements
The authors truly acknowledge the funding provided by Ministério da Ciência, Tecnologia e Ensino Superior – Fundação para a Ciência e a Tecnologia (Portugal), under grants: SFRH/BD/133894/2017, SFRH/BPD/111020/2015, and by project funding UID/EMS/50022/2013 (funding provided by the inter-institutional projects from LAETA). Additionally, the authors gratefully acknowledge the funding of Project NORTE-01-0145-FEDER-000022 – SciTech – Science and Technology for Competitive and Sustainable Industries, co-financed by Programa Operacional Regional do Norte (NORTE2020), through Fundo Europeu de Desenvolvimento Regional (FEDER)

ANALYSING FORCE REQUIREMENTS FOR AN ASSISTIVE EXOSKELETON FOR DAY-TO-DAY ACTIVITIES

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Keywords: Exoskeleton, OpenSim, Biomechanics, Gait.

Abstract.

Recent studies are predicting that, by 2060, people over 65 years old will constitute one third of the population in the European Union. These demographic changes have raised questions regarding the sustainability of the current society in Europe. Therefore, several technological solutions are being studied to prolong the active age of European citizens. One of the major problems with elders is a crescent difficulty in performing day-to-day physical activities such as walking, climbing stairs or sitting. Some exoskeletons have been identified with the ability to assist gait and other activities for elders. However, due to the presence of several other functionalities beyond the more common day-to-day activities, these devices are generally large and eye-catching, which makes their widespread adoption more difficult.

For this reason, the authors are developing an active exoskeleton with the sole function of assisting gait and other daily activities for the elder population, or some victims of stroke and neural disabilities. The exoskeleton contains actuators that assist hip flexion and extension.

This work presents the studies performed to predict the behavior of the exoskeleton and its actuation requirements. The study consisted of two healthy subjects using weights attached to the body to simulate the exoskeleton and then performing normal gait; climbing stairs up and down; sitting and getting up from a chair. The tests were made using motion capture and pressure plates. The results were then adapted, exported and processed to OpenSIM to retrieve the required data.

FLUID-STRUCTURE INTERACTION ANALYSIS OF COMMON CAROTID BIFURCATION

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Keywords: Atherosclerosis, carotid artery bifurcation, fluid-structure interaction, hemodynamic, hemodynamic descriptors.

Abstract.

The rising number of strokes leads to the adoption of new and enhanced preventive techniques for the early recognition of risk situations. Its high diameter and blood separation between the internal and external carotid artery primes, in specific regions, low wall shear stress acting in the endothelial wall and the appearance of both turbulence regions and blood recirculation. The relationship between the upper above-mentioned factors and the development of atherosclerotic plaque is well known and documented in the most various literature regarding this topic.

The main goal of this work is to study the dynamic behavior of the blood flow through the carotid bifurcation considering the artery as a flexible wall. For this purpose, the hemodynamic behavior of two specific patient carotid bifurcations were analyzed, one with no visible stenosis and another one who exhibited pathology. The three-dimensional models used for the numerical simulation were obtained through ultrasound imaging. The numeric simulation was performed using the commercial software Ansys®. To define boundary conditions, namely the Womersley velocity profile and the cardiac pressure profile, a propose-developed MATLAB code was implemented. Specific velocity and cardiac pressure profiles were obtained for each patient. Simulations were validated comparing the velocity in two different time instances (systolic peak and diastolic deceleration) with the ones obtained in the Doppler exam.

Velocity and wall shear stress studies completed with the analysis of some hemodynamic descriptors allowed the description of the blood flow through the carotid bifurcation. The attained results from the flexible wall were always compared with the corresponding rigid wall model, in order to establish the relevance of this new model.

The artery wall expansion of the flexible wall model leads to blood flow disruptions, diminishing the velocity in every studied cases and leading to the weakening of the wall shear stress acting in the endothelium. The elastic recovery of the artery wall leads to an increase in the flow turbulence.

BONE REMODELLING ANALYSIS OF THE HUMERUS AFTER RESURFACING AND STEMLESS SHOULDER ARTHROPLASTIES

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Keywords: Shoulder joint, shoulder arthroplasty, stemless implant, resurfacing implant, bone remodeling, finite element method.

Abstract.

Although the shoulder arthroplasty has undergone evident advances over the last years, several complications still limit its success. New implant designs, such as resurfacing and stemless implants, have been developed to improve the long-term outcomes of shoulder arthroplasty and to provide an improved bone quality in revision operations. However, it is well known from Wolff's law that the introduction of an implant into the bone changes its natural load distribution, leading to a significant reduction in bone mass, which can compromise the long-term stability of the implant. The aim of the present study is to analyse the bone remodelling process of the humerus after resurfacing and stemless shoulder arthroplasties using three-dimensional finite element models.

The 3D geometric model of the humerus was generated from the Visible Human Project data. The resurfacing and stemless implants were modelled in Solidworks. The bone remodelling model applied is based on a global optimization criterion that considers both structural stiffness and the metabolic cost of bone maintenance. The loading condition considered comprised 6 load cases related to different positions of abduction in the frontal plane and anterior flexion in the sagittal plane. The forces applied, which included muscle forces and the reaction force at the shoulder joint, were estimated by a multibody model of the upper limb. The bone remodelling simulations were performed considering a healthy condition and an osteoporotic condition. The results were analysed qualitatively and quantitatively by comparing the bone density distribution obtained for the humerus without an implant to that obtained for the implanted humerus.

The results showed similar levels of bone resorption for the resurfacing and stemless implants. Nevertheless, the stemless implant lost less density at the implant fixation, which suggests that the stemless implants may be better supported in the long-term, and thus could lead to a better outcome than the resurfacing implants. For the osteoporotic condition, the loss of bone increased, which supports the limited performance of these implants for poor bone quality conditions.

MONITORING THE FOREARM TEMPERATURE CHANGES WHEN USING THE BODYGRIP

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Keywords: BodyGrip, forearm, hand grip, skin temperature.

Abstract.

The BodyGrip, a special dynamometer, provides information about the grip force, which can be used as a physiological parameter for fragility, pathological and rehabilitation assessments. The Infrared Thermal Imaging (IRT) is able to record large areas of skin surface temperature, which is a non-contact and safe method to assess the under skin associated physiological state with mechanical exercises.

The aim of this research was to determine the amount of skin temperature changes during and after the hand grip exercise using the BodyGrip.

For the experiments, that had taken place in an environmental controlled environment, it was used the following equipment: the BodyGrip, a forearm support, a thermal camera FLIR A325sc, a laptop and a hygrometer. A total of 13 healthy (9 males and 4 females, 26 ± 5years old and BMI of 26.0 ± 4.5) subjects were recruited from the FEUP population. There were monitored four types of handgrip exercises: 1 grip, 5 grips, 10 grips and 15 grips of 5 seconds each at maximum griping force, being those with more than 1 grip consecutive. IRT images were taken before (baseline), during (1 per second) and after (1 per second up to 5, 30, 45 and 60 seconds correspondingly) exercise. At the IRT images, 3 regions of interest - ROI (Superficial digital flexor muscle, ulnar and radial arteries) were marked to assess the temperature changes.

Results showed that the obtained average grip force was of 283 ± 80 N, being the highest temperature variation from baseline for 1 grip at the radial ROI (0.04 at the end of grip and -0.06 at 5 seconds after), for 5 grips at the ulnar ROI (-0.15 at the end of last grip and -0.15 at 30 seconds after), for 10 grips at the radial and ulnar ROIs (-0.1 at the end of last grip and 0.05 at 45 seconds after) and for 15 grips at the radial ROI (-0. 15 at the end of last grip and 0.2 at 60 seconds after).

It can be concluded that from the obtained results that the maximum temperature response from handgrip exercise using the BodyGrip was obtained at 15 consecutive grips of 5 seconds, however since it was found hard for the participants, the suggestion is to use the 10 consecutive grips and as further research the relationship between force applied and work with the ROIs temperature variation has to be investigated.

ABSTRACTS OF THE TOPIC

FIRE: FOREST FIRES

THERMAL AND FIRE CHARACTERIZATION OF COMMON MATERIALS USED IN TENTS AND CARAVANS

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Keywords: Campsites, Fire Safety, Thermal Stability, Cone calorimeter.

Abstract.

Usually campsites are very exposed to fire occurrences due to their common location in forested areas, to the existing flammable and combustible materials used in the common human activities that are able to cause fire ignitions.

In this work, carried out in the scope of the LAETA's Firecamp2 research project, it is considered fire events that may be initiated both inside and outside the Areas dedicated to camping and caravanning activities, with the latter corresponding to the possibility of fire events, initiated in surrounding areas and spreading the fire. Characterization of the combustibility, fire risk and fire behaviour of materials and equipment typically used in campsites was performed The thermal and fire characterisation and evaluation of typically used tents and caravan materials was obtain through thermogravimetric analysis (TGA) and cone calorimetry. The thermal stability of the materials was assessed with a STA Q600 from TA under a flowing nitrogen atmosphere. Fire reaction performance was assessed in a cone calorimeter, subjected to a heat flux of 25 kW/m^2 and an incident temperature of 570 °C.

The tent samples presented degradation temperatures in the range of 200-300 °C, indicating that they are mainly constituted by polymer-based materials. The caravan results were more disperse, due to the variety of the existing materials (e.g.: wood, polymers, etc.), although the samples that correspond to the exterior raw materials (e.g. rockwool and metal) did not degraded in the testing range, having an excellent thermal stability. The cone calorimetry also demonstrated the lower suitability for tents than caravans for fire situations, because the tents materials had a rapid ignition. It was verified that some of wood based materials, in the caravans, had in their composition matrices resistant to fire. The polymer based materials of tents and caravans demonstrated the worst fire behaviour and, thus, in a fire situation, the tents are expected to have a worse performance when compared to the caravans. The legal/normative documents indicate that the polymer materials have a fire resistance E-F, which is in agreement with the obtained results.

CAMPING AND CARAVANNING CAMPSITES FIRES: AN EXAMPLE

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Keywords: Fire Safety, Camping, Caravanning.

Abstract.

The general and specific objectives of the FireCamp 2 project, namely on its task 1, was review of the state of the art on Portuguese legislation correlated to fire risk on camping or caravanning campsites (or other Areas Dedicated to Camping and Caravanning Activities - ADCCA). Further objectives of the review were intended to report, not only the efficiency of the legislation in force, as well as its fulfillment, both items regarding to a further purpose to get an entire national perspective of the subject; to evaluate significant deviations or any gaps occurring between national and international reality.

The oldest document reported by the FireCamp 1, was the Decree Law No. 192/82 of May 19, creating the Rural Camping Park; an attempt by the authorities to regulate the uncontrolled activity growth of camping and caravanning, which led to major problems of overcrowding in many of the parks. In 2006, a very consistent legislative initiative emerged, giving rise to the Civil Protection Bases Law (Law No. 27, July 3) and paved the way for later legislation. In 2008 the most structurally fire safety diplomas were issued to be applied to buildings and enclosures, generally covering campsites and caravan parks. Review results have evidenced that all enacted national legislation were strictly related not directly to fire risk on campsites subjects, as were specifically intended for "similar subjects" indoor application subject's purposes, such as buildings or showrooms spaces.

On 09 August 2015 it was a detected a fire focus at the Serra da Estrela, which led to the evacuation of the Park of Pião (county of Covilhã). According to the National Civil Protection Authority sources, 173 operational people aided by 48 terrestrial and 5 aerial means, were fighting this fire. Although the Park of Pião was equipped with several obligatory means for such emergencies, fire was then at an early stage and still away from the Park; and meteorological forecasts did not indicate changes of winds on the region; by monitoring the fire evolution in real time, preventive procedures were indicated for the evacuation of the population and assets of the Park of Pião, was performed as a precaution, that is, the people who were there were asked to leave the site.

METHODOLOGIES SET ON THE FIXED WINGS FLIGHT TESTS SURVEY ON THE BOOMLAND CAMPSITE AREA

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Keywords: UAVs, high resolution digital camera, Fuel mapping.

Abstract.

Within the accountability scope assigned by LAETA-AeroG research group on the collaborative project Firecamp2 - betwixt interinstitutional research units of the consortium LAETA (Associated Laboratory for Energy, Transports and Aeronautics) - it was carried out the procedure of flight test survey by fixed wings UAVs over areas where the BoomLand Festival would be held (on the eastern shore of the Marechal Carmona Dam, 6,65 km northeast of Idanha-a-Nova, district of Castelo Branco), in order to pick up and to collect aerial images enabling thus, the characterization task of the campsite area - camping area and its surroundings. The first objective of this task was to acquire inflight aerial images obtained from high resolution cameras; following, to complement all images information obtained with digital terrain elevation models; and subsequently concluding the task with the automatic identification of points of interest from aerial photographs.

On the flight tests survey, were used two UAVs (a TwinStar II and a Skua models), each performed different flight methodologies.

UAV model TwinStar II; Flight Planning was performed after an on-site meeting with all FireCamp2 researchers locally present, in which AeroG was assigned for two areas of operation for imaging. Camera Equipment: a Foxeer Legend 1 of 16 MP, velcro fastened on the right side of the fuselage in order to counterbalance its battery installed inside the UAV, thus, to achieve a clear lens field view and making no interference with the aircraft center of gravity (C.G.). Camera specifications included image stabilization to motion compensation. Radio Control included a Futaba T8FG Super 14 Channel 2.4 GHz FASST System enabling the remote operation and a Futaba R6208SB receiver.

UAV Skua; an autonomous navigation flight by a predefined path at constant speed and altitude in order to cover the area of interest of BoomLand and to acquire high resolution georeferenced photographs autonomously with a camera for later mosaic mounting. Navigation was performed with the help of a Pixhawk PX4 autopilot with GPS information and air data. Real-time telemetry communications were done via 433 MHz modems. A 2.4 GHz system was used for manual piloting.

FIRECAMP2 – ANALYSIS OF THE CONDITIONS OF TENTS AND CARAVANS BURNING

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Keywords: Wild fires, Wildland-Urban Interface, Campsite, Camping, Caravanning.

Abstract.

The knowledge of fire risk in campsites is poorly developed despite of its high potential as can be realized in the many fire occurrences that every year affect these areas. Conscient of this fact, the Project FireCamp2 (www.adai.pt/firecamp2) aims at the analysis of the fire risk in Areas Dedicated to Camping and Caravanning Activities (ADCCA). The work hereby presented is the result of one of the tasks of Firecamp2 addressing the fire risk characterization of the equipment mostly used in the camping and caravanning activities – tents and caravans.

Several burning experiments with tents and caravans were performed in laboratory aiming at the understanding of the mechanism of combustion of these equipment. These tests were performed for the burning of single caravans, single tents and sets of tents. Different types of ignition, and this influence in the combustion process, were tested, consisting of point ignition inside the equipment, outside fire front reaching the equipment and ignition by burning embers shower. The main parameters measured were the radiation, the convective up airflow produced, the temperatures outside and inside the equipment and the mass loss decay. The variation of these parameters as function of the elapsed time after ignition for different types of equipment are presented.

The thermal and fire characterization of the typical tents and caravan materials were also measured by thermogravimetric analysis (TGA) and cone calorimetry. The samples with 100 × 100 mm2 to access the fire properties were tested in a cone calorimeter, subjected to a heat flux of 25 kW.m^{-2} and an incident temperature of 570 °C.

In the TGA test, the tent samples had similar temperature degradation (200-300 °C), indicating that they had in their constitution the same raw materials (polymer based). The caravan results were more disperse, due to the variety of the existing materials (e.g.: wood, polymers, etc.), although the samples that correspond to the exterior raw materials (e.g.: rockwool and metal) did not degraded, having an excellent thermal stability. The cone calorimetry validates the TGA results. It was verified that some of wood based materials, in the caravans, had in their composition matrixes resistant to fire.

FIRECAMP2 - FIRE SAFETY IN AREAS DEDICATED TO CAMPING AND CARAVANNING ACTIVITIES

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Keywords: Wild fires, Wildland-Urban Interface, Campsite, Imaging, Camping materials.

Abstract.

The aiming of FC2 was the study of the fire risk in Areas Dedicated to Camping and Caravanning Activities. Actually, the initial objectives were refined to the ADCCA of summer festivals (music, dancing and other festivals). The studies were based in a use case – the ADCCA of the Cultural Boom Festival that occurred in August 2016 in Idanha-à-Nova (Portugal). Fire events occurred in ADACC during the course of the project were analysed as well. From the fire events studied, we highlight the fire occurrence of the Festival Andanças (2016) causing the destruction of more than 400 vehicles.

The resume of the project results hereby presented is structured in several topics according to the following description.

- Revision of the state of the art on Portuguese legislation correlated to fire risk in ADCCA. Results have evidenced that all enacted national legislation were strictly related not directly to fire risk on campsites subjects, as were specifically intended for "similar subjects" indoor application subject's purposes, such as buildings or spectacles spaces.

- Characterization of the combustibility, fire risk and fire behaviour of materials and equipment typically used in campsites complemented by burning tests with tents and caravans with control of the main parameters like radiation, airflow velocity and temperature, among other parameters.

- Development of a numerical model to study the fire propagation due to thermal radiation, using results of the materials characterization and of the burning tests with tents and caravans previously mentioned. The model can be used to estimate safety distances between tents and caravans in campsites, as well as simulate the fire behaviour in such settlements.

- Production of tools based on the imaging of the area of the ADCCA implantation, aiming the: 1) automatic extraction and classification of features of interest from high-resolution aerial images of the area, a procedure towards the automatization of fuel maps drawing; 2) automatic detection of emerging fires using UAV aerial image capture, with both thermal and colour imaging devices.

FIRE PROTECT – STUDY OF THE EFFECTIVENESS OF WATER PERIPHERAL FENCES FOR CONTAINMENT AND SUPPRESSION OF A FIRE FRONT

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Keywords: Forest Fires, Wildland-Urban Interface, Water sprinkler system, Protection.

Abstract.

In wildland-urban interface fires, the consequences of a fire front or embers reaching settlements or critical infrastructures can be catastrophic both as human and material losses. Currently, the study of systems aiming at personal safety and fire exposed infrastructure resilience remains insufficiently developed. The Project FireProtect intends to develop, test, validate, demonstrate and promote a set of systems that allow the passive or active protection of people and critical and strategical elements exposed to wildfires. Within the developments of FireProtect, a peripheral fence with a water sprinkler system for wildfire protection of assets is hereby proposed. This fence apparently look like the common security fences that frequently can be observed limiting the perimeter of farms, gardens or other assets.

The water fence prototype is made of stainless steel, with 1.5 m height, 4 m in length, and two water sprinklers spaced on 2 m. Several laboratory and field tests were performed in order to optimize the water sprinkling procedure protocol regarding the fire auto protection of assets.

Field tests were performed for two protocols: protocol A – sprinkling of water before the arriving of the fire front; protocol B – sprinkling of water directly to the arrived fire front. The parameter of control was the reduction of fire intensity measured by the flames height or the extinguishment of the fire front with less water. In both protocols, no complementary firefighting means were required to achieve the fire extinguishment, however, fire in protocol A, the fire spread approached the fence, while in protocol B the fire was extinguished approximately 3 m before the fence.

The laboratory tests had a different purpose of the field tests. The aiming was the measurement of the sprinkled water distribution in the absence of wind as function of the distance and orientation regarding to the sprinkler. Therefore, several water collecting pans were distributed in an area downstream the sprinkler water fence. Three sets of tests with different water flows were performed. The volume of water collected by each pan after the sprinkling of 100L by a 4m fence was measured in order to plot the geographical distribution of landed water sprinkled.

JUNCTION FIRES AT LABORATORY AND FIELD SCALES

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Keywords: Junction fire, fire behavior, merging fire, dynamic effect.

Abstract.

In this work the concept of extreme forest fire behaviour denominated as Junction Fire is analysed. The junction fire consists in the interaction between two linear fire fronts which in their propagation intersect at a single point making a small angle between them. In their merging process, the phenomena of heat transfer by radiation and convection are extremely enlarged due to the concentration of energy at the intersection point. The dynamic advance of the intersection point of the two lines and the flow along the symmetry plane of the fire are analysed for symmetric conditions. It is observed that the velocity of displacement of this point increases very rapidly due to strong convective effects created by the fire that are similar to those of an eruptive fire. The modification of fire geometry and of its associated flow gradually breaks the rate of spread increase and creates a strong deceleration of the fire that ends behaving like a linear fire front. Results from laboratory and field scale experiments, using different fuel beds and slope angles and from a large-scale fire show that the processes are similar at a different scale with small dependence on the initial boundary conditions.

EXPERIMENTAL STUDY ON BURNING RATE, HEAT RELEASE RATE AND FLAME HEIGHT OF FIRE WHIRLS USING FOREST FUELS

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Keywords: Fire whirl, Extreme fire behavior, Forest fires, Forest fuels, Burning rates, Flame heights.

Abstract.
During a forest fire the formation of fire whirls can be observed, being difficult to predict its characteristics and its evolution. Due to the high thermal energy released, fire whirls can become a danger to firefighters and are, by their complexity and dangerousness, a way of extreme fire behavior that is poorly studied.
This work presents a study on the formation of fire whirls with vertical axis on wildfires at laboratory scale that analyses the influence of the variation of the following parameters: fuel load, density, fuel configuration, imposition of forced flow with different velocities through the use of fans. Comprehensive measurements were performed in order to establish correlations of the burning rate, heat release rate and flame height of fire whirls, and to clarify the similarities and differences between a fire whirl and a 'normal' fire, i.e., in which vortex formation is not observed. Fire whirl experiments were performed in a vertical channel with a quadrangular section of 1×1 m^2 with a height of
6 m, the fire whirl generator, using dried shrubs, which is a fuel mainly composed by heather (Erica australis) and gorse (Pterospartum tridentatum) quite common in forested areas in Central Portugal and in several Mediterranean climate regions.
Given the transient nature of the experiments relationships between correlated parameters or with average or extreme values were established. Comparison with similar experiments showed that the properties of the flames generated with the present configuration of the fire whirl generator are similar to fire whirls produced in other laboratory studies and with full scale fire whirls. The maximum heat release power was of the order of 1 MW which is higher than the reported values for similar laboratory tests. The results show that forced flow increases dramatically the burning rate and reduces the time needed to achieve a high rate of energy release. Comparison with results of other sources show that the flames that are generated in the present fire whirl generator are in a transition from fire whirl to pool fire regime and that it is possible to scale up some flow and thermal properties of field scale fire whirls and to derive predictive models on the basis of laboratory scale experiments.

ABSTRACTS OF THE TOPIC

ENGINEERING SYSTEMS AND ENGINEERING DESIGN

RBF-FD MESHLESS OPTIMIZATION USING DIRECT SEARCH (GLODS)

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Keywords: Meshless method, Optimization.

Abstract.

Radial basis functions are a very accurate means of solving interpolation and partial differential equations problems. The global radial basis functions collocation technique produces ill-conditioning matrices making the choice of the shape parameter and grid distribution a crucial issue. The use of local numerical schemes, such as finite differences produces much better conditioned matrices. However, finite difference schemes are limited to special grids. For scattered points, a combination of finite differences and radial basis functions would be a possible solution. In this paper, we use a radial basis function - finite difference technique (RBF-FD) for predicting the behaviour of plates. The technique, shows great potential to solve large engineering problems when compared to traditional RBF collocation method, since the conditioning of the problem is greatly improved. Still, the most favourable grid distribution and size remain open problems.

In this work, an optimization technique (GLODS) is proposed to optimize grid distribution in RBF-FD collocation method. Global and Local Optimization using Direct Search (GLODS) is suited for global derivative-free constrained optimization. Using direct search of directional type, the algorithm alternates between a search step, where potentially good regions are located, and a poll step where the previously located promising regions are explored. Previous results show the potential of the proposed optimization technique in parameter optimization for collocation meshless methods.

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3-D MODELS OF BONE REMODELLING AND BONE TUMOUR USING VARIABLE ORDER DERIVATIVES

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Keywords: Bone remodelling, Variable order derivatives, Cancer, Fractional Calculus.

Abstract.
Bone tissue is not static. Like every other part of our body, its cells are always dying and being replaced. The main actors of this process are the cells destroying bone tissue, called osteoclasts, and the cells that build bone back, called osteoblasts. The presence of osteoblasts influences the rate of increase of osteoclasts — this is called a paracrine effect —, and the number of osteoclasts also influences their own evolution — this is called an autocrine effect. Let $C(t)$ be the number of osteoclasts and $B(t)$ the number of osteoblasts. The phenomena described above can be written as

$$\frac{\mathrm{d}C(t)}{\mathrm{d}t} = \alpha_C C(t)^{g_{CC}} B(t)^{g_{BC}} - \beta_C C(t)$$
$$\frac{\mathrm{d}B(t)}{\mathrm{d}t} = \alpha_B C(t)^{g_{CB}} B(t)^{g_{BB}} - \beta_B B(t)$$

Here the α are scaling constants, the exponents g correspond to the autocrine and paracrine effects respectively, and the β are death rates (or, better, apoptosis rates).
The changes in dynamic behaviour when there is a tumour can be modelled by tuning the parameters of autocrine and paracrine effects. Models found in the literature include intricate mathematical expressions for such variations. Our research has shown that the same effect can be obtained merely changing the order of the first order time derivative in the equations above.
Finally, because there are diffusion phenomena that cause cells to move around within bone tissue, we are lead to the following model:

$$\frac{\partial^{\alpha(t)} C(t)}{\partial t^{\alpha(t)}} = \sigma_C \frac{\partial^2 C(t)}{\partial x^2} + \sigma_C \frac{\partial^2 C(t)}{\partial y^2} + \sigma_C \frac{\partial^2 C(t)}{\partial z^2} + \alpha_C C(t)^{g_{CC}} B(t)^{g_{BC}} - \beta_C C(t)$$
$$\frac{\partial^{\alpha(t)} B(t)}{\partial t^{\alpha(t)}} = \sigma_B \frac{\partial^2 B(t)}{\partial x^2} + \sigma_B \frac{\partial^2 B(t)}{\partial y^2} + \sigma_B \frac{\partial^2 B(t)}{\partial z^2} + \alpha_B C(t)^{g_{CB}} B(t)^{g_{BB}} - \beta_B B(t)$$

In our work, we study the dynamic behaviour of the above system of variable order partial differential equations and present the main simulations of healthy and pathological states.

References.

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AUTOMATIC CONTROL OF VACUUM INFUSION PROCESSES

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Keywords: Vacuum Infusion, Process Automation, Automatic Control, Adaptive PID.

Abstract.
The quality of products manufactured via vacuum infused processes and vacuum assisted liquid molding is dependent on the control of the resin progression through the fibers.[1] To obtain a complete infusion, the resin flow speed must be maintained constant throughout the progression. This avoids the formation of flaws such as dry spots which eventually results in lower mechanical resistance of the end product.
To address this issue, an automatic flow speed control solution is proposed, which aims to guarantee a desired resin progression. The control action consists of adjusting the pressure of a sealed resin container by using the feedback information given by a camera based system that monitors the system state. This automatic control system is applied to a vacuum assisted resin transfer molding experimental setup located at the INEGI laboratory facilities.[2]
The main difficulty faced when implementing an automatic control solution to infusion processes is related with the time-varying system dynamics and its unpredictable nature. The approach followed in this project implements an adaptive PID controller: the parameters of the PID controller are adjusted according to the online identification of the system dynamics. A least squares recursive estimation algorithm is used to identify the system dynamics.[3]
The experimental results show that the proposed automatic control solution is able to keep the resin flow speed progression tracking the desired reference.

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[2] Silva, Fernando (2016). «Modelação Dinâmica de um Processo de Infusão a Vácuo».
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PREVENT WINE COUNTERFEITING BY INDIVIDUAL CORK STOPPER RECOGNITION USING IMAGE PROCESSING TECHNOLOGIES

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Keywords: Image Processing, Computer Vision, Anti-counterfeiting, RIOTA.

Abstract.

Wine counterfeiting is a major problem, stretching globally. Within this context, an approach to the problem of discerning original wine bottles from forged ones is resorting to natural features of the product, object and/or material (using it "as is").

Using the cork stopper as unique fingerprint, combined with state of art image processing techniques to achieve individual object recognition and smartphones as authentication equipment formulates the presented application. It works in two phases: enrolment phase where every bottle is registered in a database using a photo of the cork stopper inside the bottle; and a verification phase where an end-user or retailer captures a photo of the cork stopper using a regular smartphone, the photo is compared with the previously stored one and it is retrieved if the wine bottle was previously registered or not. To evaluate the proposed application two datasets of natural/agglomerate cork stoppers were built totalling 515 photos. The worst case results shows 100% precision ratio, an accuracy of 99.37%, and a recall of 74.69%, using different smartphones. The perfect score in precision is a promising result, proving that this system can be applied for wine counterfeiting, and consumer/retailer security when purchasing a wine bottle.

SKYSAFE – MONITORING CRITICAL PARAMETERS TOWARDS THE SAFETY OF LIGHT-SPORTS AVIATION PILOTS

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Keywords: Light-sport aviation, Data acquisition, Classification, Prediction, Neural networks model, Decision support system.

Abstract.

With the objective of improving the safety of light-sport aviation, the SKYSAFE project actions are threefold: a) development of data acquisition systems; b) data collection, analysis and processing; and c) development of classification and/or prediction models for the monitoring of the flight safety.

Regarding the first objective, two Arduino-based devices were developed with the common objective of acquiring pilot's physiological data and aircraft flight data. Both devices measure the aircraft linear accelerations, angular velocities, altitude and attitude using an inertial measurement unit (IMU). The devices mainly differ on the physiologic data acquired. One measures the pilot's electromyography, electrodermal activity, electrocardiography and electroencephalography using Bitalino sensors, while another uses an instrumented glove to acquire the photoplethysmogram of the pilot, from which it is possible to obtain the pilot's peripheral oximetry, the heart rate and the stress level.

Tests have been conducted with three commercial aviation pilots at a six degrees-of-freedom (DOF) flight simulator. Flight and pilot's data have been acquired in three scenarios: a) prior to flight, to obtain the pilots' baseline, b) during a normal flight simulation, and c) during a flight simulation in which one of the engines fails. The obtained data was then processed prior to model development. These data complement pre-project obtained data of pilots' and flight, measured at hypobaric chamber, 2 DOF flight simulator and real flight.

With the purpose of improving the flight safety, neural network models have been developed to allow real-time assessment of pilot and flight conditions. Models were developed: a) to estimate physiological variables from the aircraft pressure altitude; b) to classify the altitude variation (and therefore the flight stage) from physiological variables; and c) to evaluate the pilot's stress level from physiological variables. The results obtained indicate these models may serve as the basis for the development of an alert system of abnormal situations, either regarding the detection of sensors failure or pilot's unexpected physiological behavior.

D-OPTIMAL DESIGN AND NORMAL BOUNDARY INTERSECTION METHODS APPLIED TO THE MULTIOBJECTIVE OPTIMIZATION OF 1045 STEEL END MILLING PROCESS

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Keywords: D-optimal design, response surface methodology, normal boundary intersection, milling.

Abstract.

D-optimal method is used in mathematical model's development for process responses. D-optimal experimental design is response surface based methodology, used for conducting the design of experiments, the analysis of variance, and the empirical modelling, and this method has some advantages compared to other response surface methods. In this study, the responses analyzed includes surface roughness, Ra and Rt, in end milling of AISI 1045 steel. Four input parameters (cutting speed, feed per tooth, axial depth of cut and radial depth of cut) and tree noises variables (tool wear, cutting fluid concentration and flow rate) are considered. Coupling the Normal Boundary Intersection (NBI) method to Weighted Least Squares (WLS) principle, an equispaced and convex Pareto Frontier were generated for the mean and variance functions derived from the respective response surface combined array.

DELAMINATION TEST FOR AN ASYMMETRIC SANDWICH COMPOSITE OF NATURAL STONE AND CORK AGGLOMERATE

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Keywords: Asymmetric, sandwich composite, cork agglomerate, stone, delamination.

Abstract.
This work presents a delamination test for an asymmetric sandwich composite of natural stone, cork agglomerate and glass-fibre reinforced epoxy. This class of structural composites is designed to have high stiffness/strength-to-weight ratios and to achieve them one of the challenges is to understand the mechanical behaviour of each component and the type of interaction between them. Being aware that delamination is known to be its principal mode of failure, several tests and standards have been developed to determine the debond toughness of a composite, but none includes testing an asymmetric designed composite made of more than two constituents (usually a core and two fibre-reinforced facesheets). This method presents an approach to further determine the delamination causes of the composite and, consequently, its limitations concerning practical use.

FRICTIONAL BEHAVIOUR OF ROLLING BEARINGS

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Keywords: Friction, rolling bearings, dynamic, multibody.

Abstract.
Precision rolling bearings are a product of the advanced technology of the twentieth century (Hamrock & D. Dowson, 1981) whose main function is to transmit load at very low friction. Still, the total power dissipated in rolling bearings can have a major contribution to the overall energy loss of a machine. For instance, the rolling bearings' power loss inside a planetary gearbox can reach up to 30 % of the total power loss (Attila & Kozma, 2010). The energy consumption in machine design has become more important, being a major concern for science and industry. The rolling bearing manufacturers are trying to improve rolling bearing designs to reduce the power loss, the energy consumption, noise, vibrations and also reduce the operating temperatures, improving the lubrication conditions and reducing the environmental impact.
According to Weigand (2006), grease is the most common type of lubricant used in rolling bearings, in fact, about 90 % of all the rolling bearings are grease lubricated (Lugt, 2013). However, there is very little work on the grease lubrication mechanisms, which rule the film formation and friction torque in rolling bearings.
In this work a series of experimental tests were performed with cylindrical thrust roller bearings (TRB) lubricated with grease. The tested greases were formulated with base oils of different grades and/or nature but also different thickener types.
The friction torque was measured under constant load, while varying the rotational speed, at different operating temperatures. The SKF's rolling bearings friction torque model was optimized to the experimental measurements by calculating the coefficients of friction (COF) under boundary and full film lubrication.
It was found that the polymer-thickened greases generally show lower friction than typical multi-purpose lithium greases. The base oils of each grease were also tested and might show quite different friction torques than the corresponding greases.
The objective of this work was to obtain the coefficient of friction of different lubricants under several operating conditions, to be used as input in multibody dynamic models. The study of the frictional forces for different operating conditions is important not only because it affects the system dynamics but also the power loss. These results are part of a larger work aiming to understand the friction interaction between rolling bearing elements (cage, rollers and raceways).