TEchMA2022

5th International Conference on Technologies for the Wellbeing and Sustainable Manufacturing Solutions

Aveiro, 27th of May 2022

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TEMA - Centre for Mechanical Technology and Automation

Pursuing excellence, cutting-edge and impact Research & Innovation since 1996

The Centre for Mechanical Technology and Automation (TEMA) has been pursuing excellence, cutting-edge research and innovation since 1996. It is the main research interface of the Department of Mechanical Engineering, aligned to University of Aveiro commitment for innovation, quality, and international recognition in the areas of Engineering Education, Research and Cooperation with Society.

In a world of constant change, the capacity of adjustment is essential. TEMA is highly aware of this factor and fully comprehends the relevance of the R&D conducted in the research unit and its impact on society (academic, industrial/business and civil) and is experiencing a crucial transition period of structural adaptation to ensure the continued pursuit of scientific excellence with a contextualized translation in(to) innovation, competitiveness and citizenship of the community.

TEMA is focused on current societal challenges and upcoming global requirements, translated into three main mobilizing projects (MP): Mobilizing Project 1 – Sustainable Manufacturing Solutions; Mobilizing Project 2 - Technologies for the Wellbeing; and Mobilizing Project 3 - Research Infrastructure, involving TEMA's members as one coherent group. MP1 is focused on the development and innovation on manufacturing engineering and technologies, with subsequent industrial applications. It is intended to increase productivity, improve products'quality and reduce waste in production processes. The strategy of the MP2 aims to increase the quality of life of society by means of engineering systems, focusing on people and their needs. MP3 aims at a rational and efficient management of TEMA's material and human resources (including its 14 laboratories), its vast array of scientific equipment in a large diversity of areas available to society, making the research infrastructure an "open facility" for several (academic, research and industry) end-users.

Recently, PM3 had new developments, namely in joint participation in two new projects (call) of the National Infrastructure Roadmap:
1 – TEMA+
With Researchers from TEMA, and i3S-University of Porto.
TEMA+ provides the physical, chemical, and structural characterization of materials, allowing the development of new products and processing techniques, in order to help promote greater efficiency and sustainability in the use of resources. The infrastructure helps companies transform science and knowledge into products, processes, and services, as well as supporting the scientific community by providing advanced laboratory facilities.
TEMA+ is made up of 18 diverse laboratories equipped to respond to a comprehensive set of services focused on academia and industry.
2 - Portuguese advanced materials surface characterization – PT|MATSURF
With Researchers from Universidade NOVA de Lisboa/I3N|NOVA; Universidade de Trás-os-Montes e Alto Douro/CQVR; International Iberian Nanotechnology Lab./INL; Universidade do Porto/CEMUP; Universidade do Minho/SEMAT|3Bs; Universidade de Aveiro/ CICECO|I3N|TEMA; Universidade de Coimbra/CEMMPRE; Universidade de Lisboa/IST; and Universidade de Évora/HERCULES.

PT|MATSURF is a distributed RI (9 nodes) covering all the universities with research efforts in Materials Science and Physical Sciences, from North to South regions, being coordinated by i3N|NOVA. PT|MATSURF is specialized in the surface analysis of advanced materials, including state-of-the-art instruments operated by highly specialized personnel. This RI is a unique and world class facility, whose investment, running, and maintenance costs are relatively high in comparison to other RIs, but whose importance and strategic character justifies its presence to the entire R&D community, industry, and society as a whole. The aim of PT|MATSURF is to provide an unprecedented collection of nano-scale surface analysis instrumentation to be used for the characterization of a wide variety of innovative materials/interfaces. The surface analysis of advanced materials has become a well-known and strategic area due to the growth of research dedicated to nanotechnology and nanostructured materials in a very large range of fields, such as microelectronics, optoelectronics, heterogeneous catalysis, anti-corrosive/anti-wear coatings, biomedicine, biotechnology, gas sensing, etc. The importance of surface analysis is constantly increasing due to the downscaling of devices and the increasing role of processes taking place on the materials surface, defining the growing demand for the surface characterization of innovative materials.
Presently, PT|MATSURF RI laboratories are equipped with major surface analysis techniques: XPS (7), UPS (3) AFM (9), TOF-SIMS (1), SAM (1), ISS (2), and REELS (1), as well as complementary thin film characterization techniques such as micro-Raman (5) and FTIR (6), representing already a direct investment of ~15 M€, which is essential for fundamental and applied research in Materials Science, Nanotechnology and Physical Sciences.
This RI has a multidisciplinary nature and aims to fill a gap of the Portuguese Roadmap of RI.
TEMA is also actively working on the new Intelligent Systems Associate Laboratory (LASI). TEMA was part of the creation of LASI, which consists of 13 Research Units(ALGORITMI Research Center; Applied Artificial Intelligence Laboratory (2Ai); Artificial Intelligence and Computer Science Laboratory (LIACC); Centre for Informatics and Systems of the University of Coimbra (CISUC); Centre for Mechanical Technology and Automation (TEMA); Centre of Mathematics of the University of Porto (CMUP); Centre of Technology and Systems (CTS); Coimbra Institute for Biomedical Imaging and Translational Research (CIBIT); Institute for Polymers and Composites (IPC); Institute of Electronics and Informatics Engineering of Aveiro (IEETA); Research and Development Unit for Mechanical and Industrial Engineering (UNIDEMI); Research Centre in Real-Time and Embedded Computing Systems (CISTER); Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development (GECAD)), with more than 500 PhD researchers. This is a unique opportunity to leverage the growth of the TEMA at all levels, from the financial to the scientific.
LASI establishes five inter-disciplinary research thematic lines to give response to social, scientific, health, sanitary, social, economic, and environmental challenges. The goal is to pave the next generation of knowledge and technologies for the development and transformation of the industry and society. In fact, each thematic line aims to tackle specific societal challenges, going from good health (UN's Goal 3), quality education (UN's Goal 4), and gender equality (UN's Goal 5), to renewable and sustainable energy (UN's Goal 7), better jobs and economic growth (UN's Goal 8), innovation and infrastructure (UN's Goal 9), reduced inequalities (UN's Goal 10), smart and sustainable cities (UN's Goal 11), Climate Action (UN's Goal 13), and boost partnerships (UN's Goal 17). Within the Portuguese landscape, the goals are also set to answer societal challenges, including demographic changes and well-being; safe, clean, and efficient energy; intelligent, ecological, and integrated transportation systems; and inclusive, innovative, balanced, and fair societies. Innovative and Sustainable Industries is a thematic line that focuses on advanced manufacturing, decarbonization, factories of future, green AI, Industry 5.0, intelligent materials and products, and collaborative robotics. On the other hand, Smart Cities, Mobility and Energy aims to promote sustainable and green cities, focusing on urban computing, intelligent transportation systems, e-Citizenship as well as intelligent environments. The Health and Well-being thematic line focuses on active ageing, ambient assisted living, and smart intervention with personalized health, biomedical informatics, and medical robotics. Infrastructures and Highly Connected Society aims to tackle all society specific challenges based on methods and techniques that include cyber security, quantum computing, computational support, internet of things, and virtualization. Finally, the Public Administration and Governance research line focuses on E-governance, digital transformation, ethics, data protection and privacy, e-Services, and fair and effective governance.

Aveiro, May 19th, 2022
The Director,
António Bastos Pereira

TEchMA2022

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LASI Intelligent Systems Associate Laboratory

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Book of abstracts

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SUSTAINABLE MANUFACTURING SOLUTIONS

Machinability of functional femoral component obtained by EBM in Ti-6Al-4V alloy

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***Abstract*— The use of additive manufacturing such as EBM (Electron Beam Melting) or SLM (Selective Laser Melting) to produce components for medical applications in titanium alloys is a technology that enables the production of complex geometries, sometimes impossible to achieve with traditional manufacturing methods. The use of this production process in medical devices results in some advantages, such as the possibility of customizing orthopedic implants [1]. The need to obtain functional regions in these components, in order for them to work for long periods of time, needs higher geometric accuracy and dimensional tolerance associated with an excellent surface finish. That tolerancing is impossible to obtain through additive methods and justifies the use of subtractive manufacturing processes as a complement to finish the functional regions [2]. This complementarity of processes is within the scope of the concept of hybrid manufacturing [3]. In this sense, it is important to evaluate the machinability of components obtained by additive methods through machining tests in order to promote their use in medical applications in the form of functional components [4].**

Within the scope of this work, it is intended to evaluate the machinability of the titanium alloy Ti-6Al-4V, through the turning of a pre-shape component produced by EBM and wrought test samples of a functional cone, according to the ISO standard, for a current medical device application. For this purpose, the differences in cutting forces and the surface finish of the surface obtained in the turning tests were registered and analysed. From the results obtained, could be concluded that EBM test samples presented lower resulting cutting forces but higher roughness. The effect of feed rate was proven, insofar as when it was increased, the resulting machining forces also increased up to about 50% for both types of materials and the Ra value to approximately 200%. After a machining finishing operation, it was possible to obtain, with the EBM test samples, surfaces with good quality identical to those of wrought titanium alloy.

***Keywords*—titanium alloys, Ti-6Al-4V, EBM, machinability**

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Generalized Fault Trees

A data-driven methodology for reliability analysis

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***Abstract*—Reliability analysis plays an important role to ensure the availability of systems. For this reason, techniques such as the fault tree analysis (FTA) have been exploited to address the reliability assessment of several systems, [1]-[3]. FTA comprises a wide variety of modeling and analysis techniques [4], allowing the modeling of failures of complex systems in a simple graphical way. A fault tree (FT) consists in tree-shaped directed acyclic graph containing two types of nodes: gates, and basic events (BEs). The BEs are the root causes of the problem or top event (TE) and the gates are operators that describe the interaction between the BEs.**

Traditionally, the TE represents the failure probability of a complex system, while the BEs represent the failure probability of his parts. Besides the FTA is a widespread technique, it requires specialized knowledge from technicians and engineers to generate the appropriate tree-shaped structure and to define the BEs, for modeling the TE. Moreover, mathematically the FTA has a known issue, the fact that it approximates the distribution of BEs to the exponential distribution. This work reports on an innovative methodology, the so-called generalized fault tree (GFT) analysis, that generate BEs directly from sensor data and allow them to follow an arbitrary compact support distribution, "in press" [5]. The BEs are generated by the discretization of continuous data in five levels: outlier low, low, normal, high, and outlier high, according to their distribution in the training dataset. Then a search process is carried out to generate the tree-shaped structure that best fits the TE distribution according to the root mean square error (RMSE). The approach shows good results, especially when applied in realist scenarios where the approximation of the BEs distribution to an exponential is a rough approximation. Furthermore, the GFT approach represents an important advance in the root cause analysis, since in the training process, the root causes of a given TE are found automatically.

Keywords— generalized fault trees; GFT; reliability analysis; data-driven

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A nonlinear topology-based optimization approach for the design of a heterogeneous mechanical test

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***Abstract*— Numerical simulation is being widely applied in the virtualization of sheet metal forming processes. An accurate reproduction of the material behavior is of major relevance for the quality of the obtained results. Material characterization and model calibration procedures usually rely on the use of a whole range of classical mechanical tests. With nonhomogeneous displacement and strain fields, heterogeneous mechanical tests have appeared to enhance this costly procedure. New specimen geometries have already been proposed by several authors, who adopted nonefficient design methodologies, for instance, trial and error approaches based on their empirical knowledge [1]. This issue can be solved using an optimization approach to find efficiently the specimen geometry that can provide the highest quantity of information about the material behavior. This work proposes a topology-based optimization methodology for the design of a heterogeneous mechanical test. The potential of topology optimization to obtain an innovative geometry consists in a major advantage of the proposed methodology [2,3]. Moreover, a mechanism design approach is used alongside the design by topology optimization to directly introduce heterogeneity in the displacement field [4]. A nonlinear finite element analysis is employed to account for material and geometric nonlinearities. The nonlinear elastoplastic behavior and the large deformations that the specimen is subjected to are taken into account in the design procedure. As a result, an optimal specimen geometry is obtained, being the heterogeneity of its stress field evaluated using a mechanical indicator. It was proved that the proposed nonlinear design methodology produces a mechanical test capable of improving the mechanical characterization of sheet metals.**

Keywords*— *Heterogeneous test; Topology optimization; Mechanism design; Nonlinear FEA; Elastoplasticity.

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Influence of fused filament fabrication parameters on the morphing ability of polylactic acid (PLA)-based materials

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***Abstract*—Fused filament fabrication (FFF) is capable of creating complex geometries by adjusting the model and 3D printing parameters. In turn, 4D printing allows the users to control the final shape of an adaptive structure with programmable configuration, having the materials' responsiveness to stimuli as the key factor. However, as 4D technology emerges from 3D printing, various challenges still need to be explored, such as the controlled morphing effect. The shape change depends on the raw material's microstructure along with the processing methods and parameters. Thus, to control the morphing ability, it is essential to precisely understand all its dependencies. Knowing that the shape-changing effect is related to molecular mobility, it becomes inevitable that it strongly depends on crystallization phenomenon of the polymeric network [1, 2].**

The purpose of this research was to understand and optimize the relationships between the microscopic properties of a polymeric filament, associated with the deposition parameters during 3D printing, and the repercussions on the morphing effect. Through a design of experiments (DoE), the influence of 5 printing parameters (printing temperature, bed temperature, speed, fan speed, and flow) was studied on crystallinity degree. The morphing effect was also explored in this study, through the hot programming process. The test samples were 3D printed using a BEEVERYCREATIVE B2X300 3D printer and 1.75 mm PLA filament from 3DKordo as feedstock. Differential scanning calorimetry (DSC) was used to reveal the crystallinity ratio of 3D printed PLA-based materials, before and after the polymer deposition. Overall, it was evidenced that the interaction between bed temperature and the 3D printing speed had the greatest impact on the response variable.

Keywords— 4D printing; 3D printing conditions; Thermal stimulus; Microstructure

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TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

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On the selection of constitutive models for realistic numerical simulations

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***Abstract* — Nowadays, the automobile and aeronautics industries are of high demand for quality and efficiency. The products and components development must be precise and with no delays. Therefore, the virtualization of these processes using numerical simulations is essentially used. Yet, realistic simulations are crucial for the correct development of the projects. For such, it is required an adequate constitutive model and accurately calibrated material parameters. Looking at the last decades of scientific research, several material constitutive models have been proposed and experimentally validated to characterize the numerical material behavior** [1]–[3]**. However, its selection is a tough and laboured task that requires specified knowledge which usually is not observed in the simulation software users in the industry. Generally, in the scientific community, the model selection strategy is based on brute force and the comparison of numerical and experimental data** [4]–[6]**. This is an exhaustive and non-robust approach. An automatic tool for the constitutive model selection is necessary to solve these problems and lead to more accurate simulations. This work analyzes the state-of-the-art regarding constitutive models and methodologies for their selection. Besides, it proposes different possible approaches to address the problem observed.**

Keywords— Constitutive models; Material macroscopic behavior; Finite Element Analysis (FEA); Selection tool.

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Prediction of mechanical properties of parts produced from reprocessed thermoplastics within an additive manufacturing framework

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***Abstract*— To use recycled plastics in the production of parts with certain functional requirements, it is important to be able to predict what properties can be expected from these materials. They suffer degradation during reprocessing, which needs to be accounted for when assigning this type of material to a new component. It is the aim of this work to predict the mechanical properties of parts produced through Material Extrusion-based Additive Manufacturing (MEAM) with thermoplastics potentially reprocessed multiple times. Given the number of variables affecting these properties and the complexity of the interaction between those variables, Machine Learning (ML) algorithms have been selected as prediction tools. Application examples of ML algorithms in this field, such as the prediction of thermal degradation in 3D printed parts with FTIR [1], or the prediction of mechanical properties in extrusion [2], have been reported in the literature. To the knowledge of the authors, ML algorithms have not been applied to the prediction of properties of parts produced through MEAM with reprocessed polymers, this being the ultimate objective of this work.**

In the current stage of development, an Artificial Neural Network (ANN) is used to achieve the prediction of mechanical properties of parts, according to the material grade and its melt-processing history. Poly(lactic acid) (PLA) has been selected as the polymer to be studied. The procedure starts with the selection of the input parameters which will feed the ANN. Data from the literature on the effects of reprocessing cycles and process parameters on the mechanical properties of PLA were collected. After being treated and selected, the relevant information was aggregated in a database, from where the training, validation, and testing datasets were extracted. In subsequent stages of the work, the algorithm will be tested and improved through the inclusion in the database of experimental data acquired inhouse by the authors. Furthermore, the database and algorithms are expected to be made available publicly, thus contributing to knowledge and to allow for external collaboration.

Keywords*— *3D printing; Recycling; Polymer degradation; Machine learning; Artificial neural network.

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Generative design to model metamaterial devices using reprocessed plastics

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***Abstract*— Polymers have wide applicability and their advent has revolutionized, simplified or even improved the way of living of humans, since it combines low price, lightweight and high durability, and can be easily converted into a wide range of products. Despite all the benefits highlighted above, the mismanagement associated with end-of-life plastic products has led to environmental problems due to their high resilience and persistence in nature, representing a tremendous burden to planet earth. It is, therefore, paramount to seek new ways to reintroduce them into the production chain.**

Generative design (GD) may be sought as a path to achieve that, since it shifts the task of the CAD programme by actively participating in the modelling process. Based on advanced algorithms such as artificial intelligence or machine learning, GD creates several physical models that optimally fit the input requirements, namely, material, volume, loads, or manufacturing process [1], [2]**.**

Additive manufacturing (AM) is pointed out as an innovative sustainable manufacturing process when allied with GD. AM is a disruptive technology that not only allows the production of complex and variable forms but also tolerates multi-material incorporation on a product. Fused filament fabrication (FFF) is an extrusion-based 3D printing technique vastly used these days due to the interesting results achievable at a low price. Another aspect that turns AM technologies interesting is the possibility to incorporate reprocessed polymeric materials [3]**.**

The advent of metamaterials (MMs) has opened a wide range of opportunities regarding engineering problems. These materials present paramount properties, that commonly can't be found in nature, by combining one or more materials with a structural design.

In the light of the above, a work plan is being developed and intends to study and demonstrate that reprocessed polymers, in conjugation with high-performance ones, can achieve metamaterials performance to fulfil the product working requirements imposed by some engineering sectors such as the automotive and aeronautics. The latter will be achieved through generative design coupled with numerical tools to produce a model that will be further used during the additive manufacturing of reprocessed polymers, strategically combined with high-performance ones, in order to achieve a metamaterial device performance. Therefore, with this work, it is expected to obtain optimised designs for engineering devices, valorize reprocessed polymers, use new ones rationally and at the same time assure its the integrity and durability.

***Keywords*— Metamaterial, Additive Manufacturing, Tailored properties, Sustainability**

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Numerical study on the texture evolution of asymmetrically rolled aluminum alloy sheets

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***Abstract* — The mechanical and physical properties of aluminum alloy sheets have raised particular interest in the automotive industry. Aluminum sheets have an excellent performance while meeting eco-sustainability and lightweight requirements. However, the cube orientation commonly present in the texture of rolled sheets (due to recrystallization) results in lower deep-drawability [1]. As an alternative to conventional rolling, the asymmetric rolling (ASR) process has demonstrated material properties improvements, such as increased strength and formability, by favoring grain refinement, the development of shear orientations, or a combination of both [2]. Although ASR promotes shear orientations, a suitable shear to normal strain ratio is required to produce shear texture components effectively [3]. Numerical analysis of rolling processes allows studying and predicting texture evolution expeditiously. The Visco-Plastic Self-Consistent (VPSC) model is a polycrystal-based formulation to predict texture evolution and macroscopic properties of materials given certain loading conditions [4, 5]. The VPSC considers each grain as an ellipsoidal inclusion embedded in a homogeneous effective medium (HEM). The HEM is described by the average constitutive law of the polycrystal. By solving the inclusion problem, in which the interaction between a grain and the HEM estimates the interaction between that grain and all the other crystals, the model returns the macroscopic stress-strain response and texture orientations during the simulations. In this work, the VPSC model is used to predict shear orientations evolution on AA6061-T4 sheets during multi-step symmetric and asymmetric rolling. Results showed that the development of shear orientations during ASR sequences depends on the shear to normal strain ratio and strain path. For lower shear to normal strain ratio values, shear components are non-existent. Shear texture components approach the ideal by increasing the shear to normal strain ratio.**

Keywords— aluminum alloy; asymmetric rolling; texture evolution; VPSC.

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Laser texturing and numerical simulation of the heat transfer fluids for Cr2AlC MAX phase

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***Abstract*— The energetic worldwide emergency demands a significant drop in fossil energies being the renewable energies a proposed solution such as concentrated solar plants. MAX phase materials, such as Cr_2AlC, are good candidates as plate heat exchangers in concentrated solar plants to achieve higher efficiency, as they present excellent oxidation and corrosion resistance, good thermal shock and relatively high thermal conductivity. This study uses laser surface texturing (LST) technology to design plate heat exchanger patterns on the Cr_2AlC MAX phase and perform numerical simulations on plate models under molten salts conduction and convection conditions, accessing temperature gradient and heat transfer behaviour.**

As a result, combined microtextures with a corrugated surface and spaced V-shape channels were obtained using LST. The parametric study indicated that the optimal channels (groves) were found for 25 W in air and 20 s of laser conditions, with approximately 145 µm width and 340 µm depth. The numerical simulation results showed that ceramics materials present better heat transfer conditions than 316L stainless steel, where Cr_2AlC and alumina only differ in 1.9% of heat flux. In addition, the corrugated surface plate with 2.6% width of the total thickness increases heat transfer by 9.8%. Also, a non-dimensional tool was developed to perform these simulations that can be applied independently of the type of material.

Keywords— MAX Phase; Cr_2AlC; Plate Heat Exchanger; Microchannel; Laser Texturing; Concentrated Solar Power; Thermal Analysis; Heat Flux.

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Characterization and functional properties of carbon nanotube reinforced thermoplastic via fused filament fabrication

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***Abstract*— 3D printed nanocomposites have attracted researchers and industry due to the combination of advanced materials with good physical properties and advanced manufacturing technology with significant potential on cost-saving and complex components building [1]. Carbon nanotube is one of the most popular nano reinforcements for composites due to its guarantee for both strength and light-weighting [2]. The aim of the present work is to study the reinforcement by carbon nanotube (CNT) for polylactic acid (PLA) composites, manufactured by fused filament fabrication (FFF).**

CNTs were firstly mixed with PLA by compounder and extruded into feedstock filaments by single screw extruder at 0.5 wt. %, 0.75 wt. % and 1.0 wt. % CNT loadings. In addition, recycled PLA/CNT was gained through diluting high-content PLA/CNT with more PLA. Then, recycled composites were also manufactured and investigated in the same way as neat PLA/CNT composites. The crystallization-melting behaviors and melt flow rate are investigated to research the printability of the PLA/CNT filament. Based on that, the effects of reinforcement content and filling design on mechanical properties (both rigidity and ductility properties) of 3D printed composites, are carefully analyzed by considering several layering configurations by tensile testing. The internal structure and behaviors of composites were morphologically characterized through scanning electric microscope and computed tomography. The deformation processes and failure mechanisms of laminated composites were also analyzed.

The results showed that the rigidity of 3D printed PLA/CNT composites were significantly reinforced without losing ductility with limited introduction of CNT. Specifically, elastic modulus was increased by 34 % (0.5 wt. %), 43 % (0.75 wt. %), and 53 % (1.0 wt. %), while the ductility, presented as elongation at break was hardly affected. Then, regarding to recycled PLA/CNT composites, even both higher rigidity and ductility were presented. The reinforcement of strength, modulus and elongation at break reached to 33 %, 55 % and 27% with 1% CNT content compared to pure PLA. In addition, the effect of infill also affected mechanical properties of 3D printed composites.

Keywords*— *Thermoplastic; Additive manufacturing; Mechanical properties; Carbon nanotube; Infill; Microstructure

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Automatic image processing routine for extracting geometric features of Ti-6Al-7Nb alloy chips

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***Abstract*—When machining metallic alloys, the deformation mechanisms at the shear zone, resultant from the interaction between the tool, the workpiece, and cutting parameters are responsible for generating different types of chips (continuous, discontinuous, segmented). Ti-alloys are known for their high hardness, as well as low thermal conductivity and have a tendency to develop segmented chips for a wide range of machining conditions. The main features that characterize this chip type are the segment spacing, the peak height, and the valley height [1]. The segmented chip morphology study is significant for process optimization, as well as for validating numerical models created with the finite element method [2]. However, the chip morphology is usually extracted via manual measurements taken from digital images of the chips, which are not suitable since they are time-consuming and prone to human error. Automatic digital image processing algorithms tend to optimize the ratio between the sample size and the consumed time, in addition it contributes to the establishment of standardized criteria for image segmentation and analysis [3].**

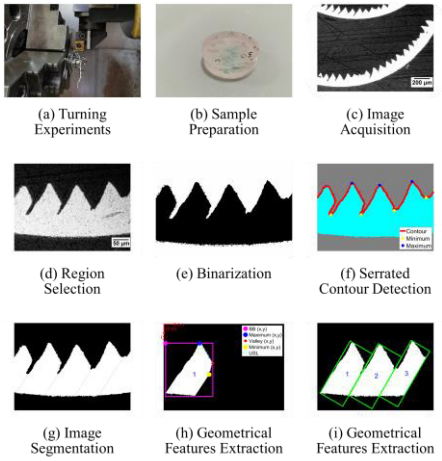

Fig 1. Experimental procedure for serrated chip evaluation.

In this work, dry turning experiments in Ti-6Al-7Nb alloy were carried out (Fig 1.a) with three levels of cutting speed (30, 60, 90 m/min) and a constant chip section (feed rate of 0.15 mm/rev and depth of cut of 0.5 mm). Afterwards, the chip fragments were mounted in epoxy resin (Fig 1.b), followed by grinding and polishing steps. The samples were observed with an optical microscope (Fig 1.c-d). Automatic binarization in ImageJ software was applied to the images (Fig 1.e). Afterwards, Matlab R2019a was used to develop a routine for detecting the serrated contour (Fig 1.f), which was used for extracting minimum and maximum points. The lines described by these points were used for segmenting the chip as shown in Fig 1.f. The morphological descriptors, including bonding box (at purple in Fig 1.h) and oriented bounding box (at green in Fig 1.i) were used for extracting the geometrical features of the metal chips. Finally, the cutting speed was related to the acquired geometric parameters. It was found that at lower speed (30 m/min) the saw-tooth shape tend to be a regular trapezoid, while at higher speeds (60, 90 m/min) it become irregular due to microcracks.

Keywords: Ti-6Al-7Nb; Dry turning; Segmented chips; Digital image processing (DIP)

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Multiscale Modelling of the Thermoelastic Behaviour of Additive-Manufactured Alumina-Zirconia Ceramics

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***Abstract*—Alumina (A), zirconia (Z) and alumina-zirconia composites (AZ) are technical ceramics that exhibit high performance in diverse applications (biomedical, aeronautics, refractories) due to their composition and structural features. Subtractive or near-net-shape conventional technologies have been used to attain functional alumina or zirconia-based components, with limitations, such as time-consuming machining with inherent increases in wastes and production costs [1]. Additive manufacturing (AM) appeared as an alternative way to fabricate complex designs. Extrusion-based AM technologies, such as robocasting, have been highly explored for ceramic-based components, although attaining dense ceramics still remains a great challenge. Multiscale modelling is a decisive tool to support the process flow and to reduce the number of experimentations. In this context, this work aims to characterise the effective thermoelastic properties of AZ ceramics, considering the influence of A/Z ratio at the microstructural (macroscopically homogeneous and isotropic material) level. Slip casting was used as conventional method to attain reference AZ samples, sintered at 1550 ºC, for which the values of Young's modulus, thermal conductivity, thermal expansion coefficient and Poisson's ratio were evaluated. Experimental, numerical and analytical (micromechanics) results were compared. Thereafter, based on the obtained microstructural results, (numerical-based) prediction models were developed for similar AZ specimens fabricated by robocasting, considering the influence of both material (A/Z ratio) and geometrical (filament diameter/spacing and overlapping ratios) effects at the macrostructural (macroscopically heterogeneous and anisotropic porous lattice) level. Anisotropic thermal conductivity, thermal expansion and elasticity tensors were evaluated using both Asymptotic Expansion Homogenisation (AEH) [2] and Finite Element Method (FEM) techniques.**

Keywords— Additive Manufacturing; Robocasting/Direct Ink Writing; Alumina & Zirconia; Technical Ceramics; Thermoelastic Properties; Multiscale Modelling; Finite Element Method

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Optimization strategies towards quality improvement of family injection moulded parts

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Abstract— Injection moulding is a very versatile, highly automated and economic process to obtain thermoplastic parts. This versatility allows for implementation of very complex injection moulding tools such as "family mould" which is the tool containing multiple cavities of varying shapes and sizes for production of parts to be used in a product assembly [1]. When the mouldability rules are strictly followed, it is possible to achieve high quality parts also assuring aesthetic requirements such as uniform colouring, essential for this kind of product, since the assemblage components are moulded simultaneously and not from plastic of different batches. However, efficient production of these components is still a challenge as the family moulds usually contain impressions of different shapes, volumes and thicknesses, dictating that filling should be balanced in order to assure part dimensional stability, at the lowest possible processing residual stresses. The latter becomes even more critical when family moulded parts are subjected to secondary post-processing operations as electroplating where high residual stresses may result in deficient adhesion of metallic layer and warpage [2,3]. To lessen the probability of these defects, a synergetic approach is required addressing simultaneously optimization of two critical aspects: mould feeding system design and processing conditions. However, it should be stressed that it is not always possible to obtain a perfect set of the processing condition which addresses every quality criterion equally for such unequal family mould parts and, hence, some compromises are unavoidable. The work here presented investigates different optimization strategies aiming at improvement of dimensional stability and reduction of residual stresses in family moulded Acrylonitrile Butadiene Styrene (ABS) lid and flushing buttons of a toilet cistern. These parts, when subjected to electroplating, present poor adhesion and peeling of the metallic layer as well as distortion beyond the allowed tolerances in the Z axis, resulting in their total rejection. The numerical simulation, carried to identify the defects and their probable causes, revealed several problems that might affect the moulded parts quality such as: very high clamp force, warpage due to non-uniform cooling and unbalanced filling patterns between the cavities. The latter was aggravated by the hybrid feeding system rendering balance even more challenging. To address these issues, first the profiled injection velocity and packing pressure were applied in order to maintain a constant flow front velocity in the mould, and to minimize overpacking in an attempt to remediate the consequences of the unbalanced filling. At the second stage, the hybrid feeding system was modified to obtain a more balanced filling. Moreover, a Design of Experiments (DOE) based optimization methodology was carried out by varying the profiled injection velocity and packing pressure. These corrective actions resulted in the reduction of the warpage within the established tolerances and a significant reduction of the Mises-Hencky stresses, indicating a potential for minimization of the electroplating defects.

Keywords— Residual stress; Optimization; Family mould, Warpage.

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Life Cycle Analysis of a plastic toilet cistern

tradition vs. recycled processing

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Abstract— Plastic is profoundly embedded in one's daily lives. Due to its low cost, light weight, malleability, and other characteristics, it can be used in a wide range of applications. Nevertheless, careful life cycle analysis of plastic products is crucial.

The Life Cycle Analysis (LCA) methodology is one of the most important tools to evaluate the environmental impact of a product throughout its lifetime, from the production stage to end-of-life disposal [1]. It allows for the comparison of different alternatives [2] and to assess the potential positive and negative impacts [3].

In this scope, it becomes crucial to study the recyclability of different polymeric materials, as well as their resulting material properties, in order to determine if the recycled plastic can be incorporated into products, without compromising the required performance. Moreover, the overall environmental gain can then be further assessed to promote product circularity.

The work here presented analyzed the industrial production of a plastic toilet cistern and, resourcing to LCA, aimed at determining the overall impact of the product.

Moreover, an experimental campaign was undertaken where material properties of several reprocessed product cycles were evaluated by tensile and flexion tests, according to ISO 527 and ISO 178, respectively. The results have shown that for the reprocessed number of cycles studied, the material degradation and the loss in mechanical properties enabled a revalorization by reprocessed plastic incorporation. Furthermore, three new life cycle scenarios were envisaged and compared to the traditional process to establish and determine the environmental gain of incorporating 10%, 20% and 30% of recycled plastic during the production of a plastic toilet cistern. The results obtained indicate that the incorporation of recycle plastic leads to lower environmental impact, when compared to the tradition processing. Moreover, higher percentages present inferior environmental impact.

The study of plastics life cycle plays an important role in the transition to a more circular economy and a more sustainable quality of life on Earth. The research work presented is show that to move towards that goal, it is vital to study the thermo-mechanical properties of recycle plastics and determine their potential to be reincorporated into new products.

Keywords— Life Cycle Analysis; Environmental Impact; Plastic product; Recycle plastic.

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Process parameters optimization of LMD based on numerical simulation and mathematical modeling

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Abstract— Laser metal deposition (LMD) has been accentuated by various industries due to having flexibility to produce complex geometry and manipulating the mechanical and microstructural by controlling the process parameters [1-2]. In this process, various parameters such as laser beam diameter, laser scanning speed, powder federate, gas flow rate are important and need to be controlled for having desired geometrical, mechanical and microstructural properties. Also, in this process, the part is produced based on layer by layer deposition with rapid solidification and cooling and these phenomena create some defects such as residual stress and shrinkage but by controlling theses phenomena, mechanical and microstructural properties can be improved. In the current research, the LMD process is simulated via Simufact and Marc software to optimize the process using Response Surface Methodology (RSM) based on the previously-implemented experimental results [3]. A series of 17 tests based on the Box-Bhenken Design of Experiments (DOE) approach has been implemented to reduce the residual stress and deflection. The input parameters in the current study are laser beam diameters, laser scanning speed and laser power. To evaluate the residual stress, the average value of residual stress on the top surface of first layer has been measured. Moreover, to check the deflection, firstly, the area where the maximum deflection occurs is found, then the average value of deflection is measured. Afterward, by measuring cooling rate [4], the mathematical predication of Dendrite Arm Spacing (DAS) is done and the type of final microstructure is predicted. In the last stage, the optimal combination of parameters is determined and confirmatory test is done to check the accuracy of given parameters.

Keywords— Laser Metal Deposition, Numerical Simulation,Response Surface Methodology, Residual Stress, Deflection, Secondary Dendrit Arm Spacing.

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Intelligent control system applied to laser transmission welding

A novel approach to laser transmission welding parameter control

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***Abstract*— With the introduction of industry 4.0 concepts in the general industrial landscape it is important that companies maximize their productivity to remain competitive in today´s economy. In this paper, a novel approach to the control and monitoring of laser transmission welding parameters is proposed. It consists of not only communicating the known parameters for the production of a specific part automatically, but also critically evaluating these parameters, preventing defects. For this, a machine learning model is used. To choose the most suitable algorithm for the task, a comparative study between 2 different types of algorithms (XGBoost and Artificial Neural Networks) is going to be conducted. Their performance will be compared after being subject to hyperparameter optimization through the Taguchi Method. This method has been used in the literature in hyperparameter optimization to great effect [1]. On the other hand, the parameter communication is achieved through a server developed using C#. This server can communicate with a SQL Server database to retrieve the part parameters, feed the machine learning algorithm, and actuate the parameters to the programmable logical controller (PLC) associated to the laser welding equipment. All the relevant process information is communicated to the operator via a graphical interface developed using Node-Red. All the above-mentioned modules are going to be fitted to a Raspberry Pi 4, to allow the flexibilization of their use in an industrial environment.**

Keywords*— *Machine Learning; Laser transmission welding; Parameter fine-tuning; Taguchi Method; Automation.

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Buildings Operational Performance Analysis

Evidence-based calibration with uncertainty and sensitivity analysis

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Abstract— In the mid-1970s, the oil shock triggered a wave of energy conservation activities. This led to the generalized initiation of demand-side management projects geared to the building stock [1]. Many initiatives have been developed to build more sustainable buildings since the construction sector is responsible for almost 40% of total final energy consumed globally [2]. In response to current high and ambitious sustainability goals, as the focus is to reduce the energy demand of the buildings, the building simulation has emerged, used as an endeavour to imitate reality to study and optimize the building's operational performance [3].

Despite all efforts to ensure that buildings meet efficiency requirements, several studies performed recently have emphasized considerable discrepancies between the measured and the simulated building energy performance [4]. Not being clear which are the main parameters contributing to the recognized systematic gap, the problem has become an elementary concern in the field of energy performance simulation, resulting in an increasing interest in the calibration and validation of buildings simulation models [3]. To contribute to the resolution of this problem, this work will develop a procedure for validating energy models to simulate the operational performance of buildings that guarantee the quality of the model and its widespread use credibly.

Although building simulation is an increasingly common practice, it is virtually impossible to evaluate all possible variations when constructing models that mimic complex real-world physical processes because of the considerable number of interdependent input variables. Even if the simulators currently used are increasingly powerful, comprehensive and subject to standardized validation and verification processes, the complexity of buildings as a thermal system leads to the need for simplifications and adjustments that can have a relevant impact on the quality of the results obtained [2]. In addition, the lack of sufficient and reliable information about the operation of the building to use as input data for simulation models leads to uncertain results that do not fully represent reality. The lack of a harmonized and officially recognized procedure for model calibration and validation criteria, and the current guidelines which do not account for uncertainty in model inputs and predictions, lead to a lack of confidence in buildings' energy performance simulation outputs.

Considering the above, this work will contribute to the definition of a standard procedure for validation and calibration of energy models, which does not exist yet. It will also contribute to the knowledge of the main variables to be measured, their quantity and quality, and the types of equipment, sensors and instruments used in the acquisition, treatment and analysis of real energy consumption and environmental measured data. Applying the methodology to be proposed in this work, using a monitored database, a building energy model evidence-based calibration will be performed with case study buildings. These issues are important to achieve the reductions in buildings energy demand required by the global sustainable development goals, given the great contribution that the buildings stock in the construction sector can provide.

Keywords— Building energy simulation; Operational performance analysis; Model calibration; Data access; Uncertainty analysis.

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Constitutive models and statistical analysis of the short-term tensile response of geosynthetics after damage

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Abstract — Geosynthetic is a generic name given to planar products, mostly composed of thermoplastic polymers, and used in contact with soil, rock or with any other material as part of a construction system [1]. Geosynthetics have several functions and may perform more than one simultaneously, such as soil reinforcement, stabilization of steep slopes, filtration, drainage, fluid barrier, erosion control and coastal protection [2].

The objective of this research was to analyse the short-term tensile response of three geosynthetics using the procedures described by [3], and to apply constitutive equations to represent the nonlinear behaviour of the materials. Data on specimens of a nonwoven polypropylene geotextile (GTX), a woven polyester geogrid (GGR) and a reinforcement polyester geocomposite (GCR) were analysed. Some specimens of each material were submitted to mechanical damage [4], abrasion [5], and mechanical damage followed by abrasion. Nonlinear regressions of the experimental data were performed to fit the load-strain curves to a hyperbolic-based equation depending on the tensile response of the geosynthetic: type A (GTX) or type B (GGR and GCR) [6]. For each geosynthetic, the results of damaged specimens were statistically compared to those of the undamaged specimens to observe the influence of the induced damage on the tensile behaviour of the material. Experimental data were statistically compared with those fitted by the constitutive models to verify if the tensile properties were properly estimated – namely the secant stiffness for 2% strain, the ultimate tensile strength, and the strain at maximum load.

For the GTX, significant changes in tensile properties occurred only after mechanical damage followed by abrasion. For the GGR and the GCR, abrasion was the predominant damage due to considerable changes in the tensile properties and the shape of the load-strain curves. In general, the hyperbolic-based models presented good approximation of the empirical data. Curves for damaged materials were plotted using undamaged model parameters and applying adjustment coefficients and reduction factors allowing for damage, in which the goodness-of-fit was considered promising.

Keywords — Geosynthetics; constitutive models, hypothesis tests, tensile response; mechanical damage, abrasion damage.

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Experimental study on asymmetrical rolling of aluminum alloys

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Abstract— One of the challenges of the current industry is to find technological solutions that aim at sustainable development. This requires the use of materials that can be adapted to this principle, both from an economic and ecological perspective. In this sense, aluminum alloys have been a focus of interest within the automotive industry for a long time due to the adaptability of their properties to the requirements of manufacturing in this sector [1,2]. Consequently, the possibility of improving these properties through different processes is fundamental for scientific researchers in the field of engineering.

In this context, the rolling process is a metal forming process recognized for its simplicity and low cost, which could improve the intrinsic properties of aluminum alloys, as mentioned by the recent review paper of Vincze et al. [3] The present work consists in a study of the possibilities of improving the AA6022 aluminum alloy through the application of different rolling routes, specifically: Conventional Rolling (CR), Asymmetry Rolling Continuous (ASRC) and Asymmetry Rolling Reverse (ASRR). The asymmetry in the rolling process was imposed by the difference between the angular speed of the rolls. Thus, for conventional rolling (or symmetric rolling) was used a speed ratio of 1 while for asymmetric rolling was used a speed ratio of 1.36. After rolling, the mechanical properties of the material were analyzed by uniaxial tensile test.

A progressive increase per pass could be noted in the yield stress and in ultimate tensile strength of the material. This effect occurred in all rolling routes. In contrast, the total strain of the material was decreasing with the increased number of passes. At the same time, when comparing the values associated to each rolling route, it was observed that the values of yield stress and maximum stress were slightly higher in CR than in ASR. On another hand, the maximum total strain value also corresponded to CR. Regarding asymmetric rolling, both ASRC and ASRR show similar results.

In this work it was verified that all the experiments carried out raised the yield stress and maximum stress of the material, which validates the potential of the rolling processes use in industry. However, for the selected reduction per pass and routes, it was not verified that the ASR is more adequate to improve the mechanical properties of the AA6022 compared to conventional rolling.

Keywords— asymmetrical rolling; aluminum alloys; mechanical behavior

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Effects of heat treatment on conventional and asymmetrical rolling of aluminum alloys

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Abstract — High-strength aluminum alloys are an essential solution to improve efficiency and safety in transportation. In this work, it was studied the influence of heat treatment conditions on the mechanical properties of AA6022 - T4 alloy sheets previously rolled.

The rolling process is indispensable to produce sheets metals. The methods used in this work are symmetric rolling, asymmetric rolling continuous and asymmetric rolling reverse. The thicknesses reduction per pass was 30% and the total thickness reduction was 50%. Asymmetric rolling is an innovative form of rolling that emerged with the aim of improving material properties during the process [1]. However, while the stress is increased drastically, the formability of material decreased. Thus, a heat treatment is necessary to apply to increase the formability. The objective is to find the adequate heat treatment in order to increase the material formability without to decrease the stress.

The 6xxx series alloys are heat-treatable aluminum alloys that gain strength by thermal processing rather than mechanical deformation and have good formability, weldability, machinability, and corrosion resistance [2]. Previous work shows that the adequate range of temperature for AA6xxx series seems to be between 150ºC and 200ºC. Thus, the temperatures selected in the present work are 200ºC/30min, 150ºC/30min and 250ºC/15min.

The material properties were evaluated by uniaxial tensile tests using a Shimadzu AG-X plus 100 kN tensile test machine. The deformations were measured by Digital Image Correlation - GOM system coupled with ARAMIS 5M software. These measurements were performed on the samples after rolling and after heat treatment conditions, to analyze the variations in the mechanical properties of the alloy influenced by the time and temperature of the treatment.

The results show that the best combination of the mechanical strength and elongation is obtained for 150ºC during 30 minutes. Regarding the effect of the rolling routes, it seems that is irrelevant.

Keywords— Rolling, Heat-treatment, aluminium alloys

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Plastic waste as optimum feedstock for CD-based anticounterfeit tracers

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***Abstract*— The fabrication of luminescent carbon dots (CDs) which allow the design of unique optical fingerprints in a polymer matrix, is a novel and exciting technology for tracing and security control of polymeric products. CDs are considered a new emerging class of 0D carbon-based luminescent nanomaterials with a size bellow 10 nm and a quasi-spherical morphology, composed of sp^2/sp^3 carbon core. They hold many advantages like low cost, broad excitation spectra, tunable emission spectra, stable photoluminescence, good water solubility and cytocompatibility. Their optical properties can be tuned by modifying size, morphology, functional groups and heteroatom doping (i.e., boron, nitrogen, and/or sulfur). These carbon nanoparticles can be obtained, in theory, from any carbon-based material.**

The focus of this work is the study of the upcycling of plastic waste, with the objective of obtaining a valuable product from common use plastic waste. Therefore, a reactor was built up for the large-scale production of CDs using most common types of polymers, namely polyethylene terephthalate (PET). The basic principle was that using a power supply, connected to the two ends of the chamber, the electric current would pass through the material placed between the two connectors (+/-). Figure 1 is a picture of the first experimental setup used.

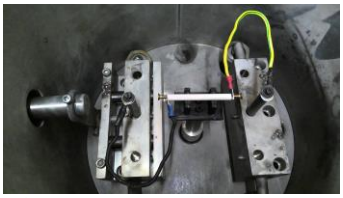

Figure 1 - Flash Joule Heating chamber.

The experimental procedure is known as Flash Joule Heating (FJH), since the material is heated to a temperature exceeding 3000 K in milliseconds, due to the electrical current (Figure 2).

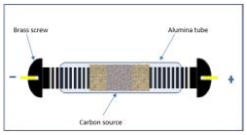

Figure 2 - Schematic of the FJH.

The polymeric material has very low electrical conductivity so the use of a conductivity booster (carbon based) was needed to promote the reaction. The polymeric material is then converted to a very high-quality graphene, which in turn would give rise to the desired CDs [1]**.**

There are endless possibilities, but the aim is to explore the produced CDs as a fingerprint for the traceability and security of any polymeric-based product that can arrive to the end consumer, contributing also to the ever-growing problem of waste management.

Keywords*— *Sustainability; Traceability; Quantum carbon dots; Recycled polymers.

ACKNOWLEDGEMENTS

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   b. Nanoengineering & Bio-inspired Manufacturing

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Sustainable and Eco-friendly Cork Composites in Aerospace Engineering

Educational Perspective for Cork Composites in Aerospace Applications

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***Abstract*— Materials science is continuously being developed, and major industries take advantage of cutting-edge technologies in their applications. Since lightweight materials with superior strength are demanded by the market, composites have come to the fore as the substituent for metal alloys. Although the technical side of industrial applications is compensated by the rise of composites, sustainability and eco-friendly properties of materials, which have important places within the EU policy areas, still require efforts from institutes and companies. At this juncture, composites produced from natural materials such as cork become more of an issue due to their environmentally friendly properties. Leading companies make investments in this issue. Still, there is a lack of human resources in the field since syllabuses in engineering programs focus on technical sides rather than the environmental effects of engineering materials. This work aims to develop educational tools for gaining environmental awareness of eco-friendly composites as well as understanding the importance of cork composites in sustainability. Within this scope, an educational scheme was developed, focusing on individuals at the college level, leading to the development of curricula, course materials, and learning platforms as well as organizing internships for the students. Staff skills are enhanced in a particular and promising field with the interactions between pacemaker partners. The industrial partner contributes to the preparation of training programs on sustainability and carbon footprint of cork products since it is a leading cork producer globally. In addition, this partner provides internship positions for engineering students. Within this scope, there is an established bridge from the homeland of cork (Portugal and Spain) to Eastern Europe, where vast amounts of investments have been paid for aerospace applications. Hence, there is a chance to have a good partnership in developing sustainable cork composites for the aerospace industry. In this work, the main target group is engineering students, while research staff also benefit from this partnership. In the current educational system, engineering students are led to pure technical courses and thus, students who graduated from engineering faculties feel a lack of environmental consciousness. This point is crucial for humanity because competition in the market leads to rapidly growing technologies, resulting in irreversible processes harmful to the environment. For this reason, technology developers, mainly engineers, should be aware of the side effects on the environment and humanity. Hence, we aim to gain awareness in the aerospace industry to use eco-friendly and sustainable cork composites. The main reason for selecting the aerospace industry as the implementation sector is that the aerospace industry is familiar with cork in aircraft, helicopters, and space shuttles. Moreover, aerospace industry is the leading sector for the development of composites since vast amounts of investments are made by the companies, resulting in significant scientific and technological developments.**

Keywords— sustainability; cork; aerospace applications.

ACKNOWLEGEMENTS

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TOPIC

1) Sustainable Manufacturing Solutions
   c. Manufacturing for Circular Economy

Classifying False-Rejections of Manufacturing Processes

A multiclass classification approach for rejection analysis in unbalanced manufacturing data

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***Abstract*—Maintenance operations are one of the primary cost factors in manufacturing, and thus improving the decision-making process naturally becomes a focus area for the sustainability of industrial practices [1]. Data-driven techniques are often suggested for maintenance decision-making algorithms as they are more generalizable than physical or mathematical models, yet capable of self-adjusting to fluid manufacturing conditions [2]. However, challenges still arise due to the heavily skewed nature of industrial data, particularly for fault or rejection classification, as these represent rare, yet costly, events, leading to the phenomenon of data unbalance. Insufficient number of representative samples hinders correct identification of decision boundaries [3], further aggravated by commonly requiring fault categorization or root cause analysis (RCA) applications to be written in terms of a multiclass problem [4].**

In this work, we propose a data-driven approach based on a novel supervised machine learning (ML) ensemble algorithm for multiclass classification for use with unbalanced datasets in preliminary RCA procedures. During training features are dynamically extracted whether through statistical inference; the combination of existing features together with compensation factors; or by injecting additional features derived from expert-knowledge. Then, the multiclass classification problem is simplified into multiple sequential binary classifications employing both ML and rule-based classifiers, all independently optimized for each corresponding pair of target class and generated features. Finally, at every classification phase, the number of unlabeled instances is effectively reduced, leading to an iterative reduction of problem complexity. The proposed solution was validated using a seven-class real-world dataset, with deep class unbalance (minority class represented under 1% of all data, and majority class over 90%), achieving results of over 90% in macro F_1-score.

Keywords*— *Machine learning, multiclass classification, unbalanced datasets

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Development of sustainable visual communication boards based on circular economy principles and environmental performance evaluation

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Abstract— The emerging interest regarding circular economy-based manufacturing is centered on the resource depletion and increasing production of waste which has been putting pressure against the sustainable development of society [1]. The production of visual communication boards (VCB) and, particularly whiteboards, is essentially comprised by the permanent bond of three main components, namely a substrate, a writing surface, and a protective back cover, a process which jeopardizes its dismantlement and further recycling, thus contributing to a poor product circularity [2]. In this context, to accomplish a circular economy-based manufacturing cycle for VCB, rethinking the product, as a whole, is paramount.

In the current work, environmental performance assessment was carried out to three Cradle-to-Cradle® certified whiteboards based on a lacquered steel, enamel-coated steel, and melamine-coated MDF writing surfaces, respectively, by making use of the lifecycle assessment (LCA) software SimaPro 9.3 in a gate-to-gate perspective (i.e., including the production and assembly stages). Origin of material, transportation to the user and final disposal of the boards were not analyzed. From this analysis, it was concluded that the different products have similar environmental performance. However, it was highlighted that the melamine-coated MDF whiteboard had a better environment impact score due to the fact that it uses less components (the coated substrate is also the writing surface), thus contributing to a decrease in material and energy consumption in the production stage.

From the assembly perspective, it is known that decreasing the number of components, decreasing energy consumption, and preventing waste would possibly provide a product with an equally decreased environmental impacts on the production stage [3]. Moreover, decreasing the number of components would also eliminate the requirement for permanent bonds, thus fostering the design for disassembly/recovery, which is crucial to establish enhanced product circularity [3]. By following these hypotheses, a novel VCB is sought to be achieved by focusing on eliminating toxic materials, such as glues, which are a known source of volatile organic compounds (VOCs) [4], as well as replacing the current substrate for a recyclable and durable material capable of being coated with a hydrophobic writing surface. The obtained VCB should be able to provide extended service life when compared to the current products and enable a circular end-of-life disposal pathway, thus strengthening the environmental commitment and allowing for new value-added market opportunities.

Keywords— lifecycle assessment; product circularity.

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Intelligent sustainable plastic product design through machine learning and DfX

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Abstract— The world lives today in an information era where data from multiple sources are stored for future utilization. With the processing power available the information is processed by a multitude of entities to extract useful knowledge. With big data (BD), processing can be done by machine learning (ML) algorithms, which require substantial amounts of data to make accurate predictions and extract patterns. However, integrated product design and development is not yet covered effectively due to the nature of the process. Product lifecycle management (PLM) systems allow for the collection of consistent data originating from the entire lifecycle, leading to huge amounts of varied and complex information.

There are some studies that investigate the possibility of integrating BD and PLM, but research on implementation is poor. Nevertheless, some development has been done in using data science (DS) with ML to make some stages of the lifecycle more efficient, mainly the manufacturing process [1]. Work done related to the design phase is few in comparison. Nonetheless, studies have found that, not only can ML applied to product design can improve its sustainability, but also enhances its circularity [2]. In this context, DfX methodologies appear as a tool to systematize the design process, by using specific directives that take future stages of the product lifecycle into consideration and allow for an integrated approach to product design and development. There have been attempts at integrating ML during the design process, and at characterizing a product lifecycle with data, but further research is needed [3]. However, based on research, no work has been done in using the DfX methodologies as a point of entry for ML in product design. Based on this, the work will aim at standardizing data from the application of DfX directives during product development and correlate it with data from the lifecycle of the product using ML. Then, the knowledge generated will be integrated in a decision support system, also driven by ML. This information is aimed at providing support in decisions that will improve the sustainability of the product lifecycle. The presentation will set forth the initial research developed to attain the objective of applying a systematic approach in product development, with emphasis on plastics-based products.

Keywords— product design; machine learning; data science; design for X; intelligent design

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Influence of printing parameters on extrusion-based additive manufacturing of porcelain paste

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Abstract—3D pottery of clayey materials and 3D printing of porcelain material for diverse applications have received increasing attention from the scientific community. Nevertheless, it exists a lack of comprehensive research about the effects of extrusion-based 3D printing parameters with industrial porcelain paste for dinnerware, which is the stimulus for the current study. Furthermore, several crucial factors regarding the printing paste, and printing equipment, such as the amount of infill, the layer height, velocity and print speed, and the paste's flow rate, could potentially affect the coherency, consistency, and accuracy of the printed piece before and after sintering. Hence, this study conducted a series of experimental tests to examine the outcome of printing parameters in extrusion-based techniques, mainly with Delta Wasp 2040, on the final printed porcelain piece, mainly on the geometrical features and some mechanical properties.

Keywords— Printing parameters; 3D printing of ceramic paste; extrusion-based 3D printing

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Improving Energy Efficiency and Corrosion Resistance during Sealing of Anodized Aluminium

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Abstract—Aluminum anodization is an old and energy intensive process. To reduce the carbon footprint of this industrial process it is necessary to reduce its energy input. The anodization step and the sealing step have been identified as the most energy intensive process steps [1], and thus viable intervention points to reduce global process energy consumption. Some authors have attempted a variety of strategies to reduce energy consumption in anodization [2,3] This work presents the results of efforts at reducing the energy consumption of anodization process by interventions focused at the sealing stage. Attempts at reducing the energy consumption at the anodized aluminium sealing process step by varying the sealing temperature in the range (50 - 98) oC without additives and using the current method suggest that little reduction in sealing temperature is possible without degradation of corrosion resistance and/or wear resistance of the coatings [4]. Results from the present indicate that anodized aluminium profiles of acceptable quality can be produced by hydrothermal sealing in the presence of selected corrosion inhibitors using a newly developed method, at temperatures ≥ 70oC compared to ≥ 98oC currently employed in industry. This translates to about 35% reduction in the energy consumption during the sealing step and ≥ 15% reduction in energy consumption of the entire anodization process. In addition, profiles produced according to this method manifest superior corrosion resistance and self-healing capabilities.

Keywords— aluminium; anodization; sealing; hydrothermal; energy efficiency; carbon foot-print; sustainability; corrosion resistance.

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TECHNOLOGIES FOR THE WELLBEING

Artificial Neural Network Modelling of Solar Thermal Hybrid Façade

Experimental Results

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Abstract— Climate change and sustainable development are the main 21st century mankind challenges, most probably the greatest challenge we ever faced. Technology has reached a point where it becomes affordable for anyone in developed countries to produce the energy they use. Production and use of renewable energies applied in a producer-consumer paradigm can become a synonym for sustainability (supply-to-demand matching), energy efficiency (closer production and consumption means less energy transport losses) and security of supply (the produced energy is endogenous). Complementary, the cost of renewable energy is becoming increasingly lower passes because the technology is well known, devices are financially more affordable and energetically more efficient. This work intends to demonstrate the potential of renewable energies namely the role which could be played by a hybrid solar thermal façade capable of heating air and water, air cooling (using a geothermal network) and ventilation. Besides its residential utilization, the façade can be used in alternative contexts, such as: industrial processes with low enthalpy requirements, commercial buildings, hospitals and hotels. The economic/financial analysis of the solution is a rather important factor that may decide the viability of such a façade in a given location. To provide such information a model of the façade was created using an Artificial Neural Network (ANN).

The use of artificial neural networks in various applications related with renewable energies, energy management in buildings and thermal systems analysis has been increasing significantly over the years [1]–[3]. This technique has, however, a different approach when compared with others as it uses and depends on data collected previously from a working prototype or a simulated system. This data ought to characterize the system behavior/performance and can be used afterwards for training the network which will be used to replicate the façade's working behavior. Thus, it is necessary to measure and monitor a set of factors, which will follow.

For the air and water circuit:

- **Inlet fluid temperature.**
- **Outlet fluid temperature.**
- **Fluid velocity.**

A pyranometer was used to measure the solar radiation incident on the façade plane. The building inside and outside temperatures were also registered/monitored.

The collected data will allow not only the creation of the ANNs but also the characterization and assessment of a series of factors related to the energy performance of the façade, such as: device efficiency and energy produced daily for the various working modes (air, water and hybrid) under different weather conditions, for the upper and lower half of the facade, and its entirety.

This paper intends to illustrate the obtained experimental results.

Keywords— Artificial Neural Networks; System Modelling; Solar Thermal; Renewable Energy

TOPIC

2) Technologies for the Wellbeing
   a. Multiscale Technologies and Devices for Medicine, Environment & Energy

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Numerical modelling of the female head-neck system

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Abstract— It has been 20 years since sex and gender differences were first seen in brain injury research. Yet, most women, their doctors, courts and other intervenients are still unaware of the main differences in terms of injuries outcomes regarding male vs. female head-neck systems. The BAFHTA (Biomechanical Analysis of Female Head Trauma) project directly addresses such questions in order to promote gender equality in terms of studying the particularities of traumatic brain injury for female individuals, once the vast majority of literature either does not perform such distinction or just address male patients. The different morphology and physiology of women's body are already reported in the literature and likely to give distinct outcomes for the same traumatic event [1-3]. Wellbeing is addressed once traumatic brain injuries and their effects, in short or long time, are a substantial parcel of illnesses among populations, sometimes called the silent pandemic [4].

Advanced numerical models of female head-neck systems are being created to allow studies and simulations to aid a better understanding of female concussion and other brain traumas, sometimes coming from domestic violence and abuse, allowing courts to properly envision and treat such cases promoting better justice for all and a more peaceful society.

Keywords— head injury, gender differences, finite elements, road safety

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TOPIC

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   a. Multiscale Technologies and Devices for Medicine, Environment & Energy

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Capacitive detection of bone-implant aseptic loosening for instrumented implants

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Abstract— Osteoarthritis, the principal reason for knee and hip replacement surgeries, has a global prevalence of 4% [1]. Although arthroplasty is considered a successful surgery [2], the revision burden is still high: implant failures can exceed 10% (6% after 5 years and 12% after 10 years) [2]. Furthermore, the risk of revision surgery is higher in younger patients and sustained increases exceeding 60% are expected over the next two decades [3]. Currently, the bone–implant fixation monitoring and the decision for revision surgery is based on imaging methods. These methods have low accuracy in detecting early loosening stages and cannot be performed throughout the daily life of patients. By consequence, they cannot establish high-performance osteoinduction and osteoconduction processes according to personalized requirements [4]. To detect bone loss stages, research teams already proposed the following methodologies: acoustic, vibrometric, magnetic induction, deformation, and bioelectric impedance [5]. Although these technologies provide significant advances relative to imaging methodologies, they are not able to effectively monitor the different loosening stages. The following problems still need to be addressed [5]: (i) provide flexible integration to sensing systems inside the instrumented implants; (ii) provide an easy way to redesign the detection technologies for different geometries of implant surfaces; (iii) provide target-oriented monitoring of peri-implant regions; (iv) provide continuous monitoring of patients during their daily life. Instrumented multifunctional implants hold the potential to monitor the bone–implant interface and deliver personalized stimulation to peri-implant tissues [4].

Research in the field of smart implants, based on a Master-Slave architecture, was conducted, and successfully demonstrated the ability of cosurface capacitive networks to (i) monitor loosening in an extended peri-implant region; (ii) provide effective sensing in interfaces with hydroxyapatite-based layers; (iii) control the monitoring operation using extracorporeal informatic systems.

Keywords— Smart Implants; Capacitive Sensing Systems; Aseptic Loosening.

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Automatic code generation for embedded model predictive control: application to a water heater

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Abstract — In this study, model predictive control (MPC) is applied to control a thermal process of domestic water heaters, namely, tankless gas water heaters (TGWH). In this system, fluidic and thermal dynamics are nonlinear, with time-varying delays dependent on unpredictable hot water demand. By improving the control performance, is possible to reduce the impact of temperature overshoots and undershoots and thereby improve user comfort, reduce water and energy wastage and associated emissions [1].

Due to the technological advancement in electronics, there is an increasing number of microcontrollers in home appliances. Modern domestic water heaters rely on electronic sensors and actuators, with closed-loop control algorithms implemented on low-cost microcontrollers.

Several strategies were proposed to improve TGWH water temperature stabilization, some based on additional hardware, others based on advanced control strategies. Some of the most promissory control approaches are model based such as predictive and adaptive control. However, the application of MPC embedded on computationally limited hardware, typically used in mass-produced appliance, is challenging. MPC algorithms have relatively high computational demands, and low-cost embedded hardware are usually characterized by limited computational capabilities and memory constrains. MPC implementation requires that a quadradic problem must be solved in real time at each sampling period.

A code generation tool, µAO-MPC [2], tailored for linear time-invariant discrete-time MPC, is used to automatically generate C code. MATLAB scripts are used to systematically perform model discretization and linearization, with different parameters and operating points, to generate input files for the code generator software.

Simulation and experimental tests were performed on a Virtual Test Bench [3] to evaluate controllers performance. Hardware-in-the-loop methodologies are implemented with 8, 16, and 32 bits microcontrollers.

A successfully implementation of embedded MPC, applying automatic code generation approach, is described. The case study of TGWH temperature stabilization under fast disturbances is presented. Simulation and experimental data, supported by hardware-in-the-loop techniques, present improved performance over classic control strategies.

Keywords— domestic hot water; tankless gas water heaters; model predictive control; embedded; code generation.

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Economic analysis of the contribution of wind energy with storage through batteries in the energy system of Cabo Verde.

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Abstract—Despite the free availability of wind, the technologies to transform it into electricity have costs that must be considered when deciding whether wind farms are the best option, with a view to sustainability and energy security. Thus, the evaluation of the cost of the electric energy produced must be based on methods that allow obtaining comparable data and allowing the best decision to be taken. For the intended study within the scope of this work, the RETScreen [1] software was adopted. The economic feasibility analysis focuses on the case study (Cape Verde archipelago) considering reference values, such as fuel prices and energy sales prices to the final consumer and the estimated upper limit for the storage cost of energy [2]. The analysis methodology is based on the variation of the energy storage cost (€/kWh) and the electricity sales price (€/kWh), keeping the other parameters unchanged and comparing the results in relation to the IRR, NPV and the Payback period at three levels, considering: (i) the wind energy contribution to the grid equivalent to 53.6%, (ii) wind energy integration into the grid at 75% and (iii) a perspective of a 100% renewable system based on wind energy. For each level of wind energy integration, different storage cost scenarios are defined, and an attempt is made to find the minimum electricity tariff for which the project becomes economically and financially viable. It is concluded that it is possible to reduce the average cost of selling electricity from the equivalent of €0.26/kWh practiced in the Cape Verde market in 2018 [3] to €0.19/kWh, with the integration of 53.6% of wind energy considering the storage cost at €409.22/kWh. The results show that for wind integration levels above 75%, it is only possible to obtain electricity tariffs below €0.26/kWh if the storage cost is reduced to values below €409.22/kWh; for the reduction of storage costs to 127.85 €/kWh the sale price of electricity could approach the average price practiced in Europe in 2018 (0.2113 €/kWh) and the minimum tariff practiced in Europe also in 2018 (€0.10/kWh) [4] could also be achieved if the storage cost equals €17.05/kWh. Another important conclusion is that it is only economically viable to integrate 100% of wind energy in systems with up to 100 MW of generation capacity, if the cost of storage by batteries is equal to or less than 17.05 €/kWh, maintaining the sale price of the electricity to the final consumer, never less than €0.14/kWh, provided that other economic parameters, such as tax incentives and interest rates, are substantially altered.

Keywords— Wind; batteries; economic; electricity; energy.

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Integrating solar energy and Phase Change Materials for increased autonomy and reduced operating costs in chest freezers

Summary of project UFA+EE - Autonomous and Energy Efficient Cold Units

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***Abstract*— Domestic refrigerating, freezing appliances are responsible for a significant demand of electricity** [1], [2]**. Furthermore, refrigerating and freezing equipment are essential for food conservation and preservation. On developing countries, operating this type of equipment may be critical given the frequent blackouts and the loss of the quality of the service which affects existing electrical grids. Then again, in developed countries, the autonomy extension, greater energy efficiency, and the use of renewable sources are crucial for consumers' choices. DC compressors powered by solar energy deliver higher overall efficiency with clean construction for refrigeration appliances** [3], [4]**. Moreover, Phase Change Materials (PCMs) can be used for thermal energy storage without major mass addition. The result of their use within the present project resulted in a 9 hours of extended autonomy and 15% COP improvements** [5]–[8]**. An enhanced version of a chest freezer was hence developed catering for: 1) availability of solar power and/or reduced electrical tariffs during some periods of the day in developed countries; 2) increased autonomy and reliance on solar power in developing countries. The developed solution is distinct from conventional equipment since it integrates a solar photovoltaic panel, a direct current, variable velocity electrical motor to actuate the compressor and PCMs. Models have been developed to simulate solar availability and heat transfer under phase change processes. Control algorithms for motor actuation have been created to address rapid changes in solar energy availability due to sudden overcasting and autonomy and energy consumption have been monitored with different compressors and Phase Change Materials. The main results showed significant improvements in the autonomy (up to 40%) and a reduced cost of the energy consumed.**

Keywords*— *Increased autonomy; Phase Change Materials; Domestic freezers; Solar photovotaics; Smart Grids

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Controlled 3D electrospinning of aligned 3D matrices

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***Abstract* — Electrospinning is a versatile microfabrication technique that conveys electrohydrodynamic principles to fabricate nanofibers from a polymer solution. Given the similarity of the produced nanofibers with the native extracellular matrix (ECM) of most tissues, this technique has been extensively used in tissue engineering (TE) applications [1]. Even though electrospun scaffolds possess high porosity, pore interconnectivity, and large surface area to volume ratio, their inherent small pore size derived from high packing density of deposited nanofibers is a significant limitation of these scaffolds is [1]. In this regard, three-dimensional (3D) nanofibrous scaffolds have emerged as promising alternatives to the conventional two-dimensional (2D) structures in order to develop suitable microenvironments for cell migration and tissue interconnectivity [2]. Several approaches have been used to fabricate these 3D structures, including liquid and template-assisted electrospinning, self-assembly and post-processing techniques [3]. While substantial progress has been reported using these strategies, it still remains a challenge to precisely control fibre alignment and pore dimensions of the 3D nanofibrous scaffolds in a reproducible manner. Recently, a novel electromechanically 3D electrospinning platform was developed for the fabrication of 3D multi-layered aligned matrices in a continuous and fully automated mode [4]. Thus, in this work, this platform was used to fabricate 3D nanofibrous scaffolds with specific programmed patterns of fibre alignments for TE applications.**

A polymeric blend of polycaprolactone (PCL) and Gelatin (GEL) was used to produce PCL+GEL nanofibers placed in a collecting module according to programmed fibre alignments. The resulting 3D scaffolds' internal and superficial morphologic characteristics were assessed by microcomputed tomography (µCT) and scanning electron microscopy (SEM), respectively. Then, an immortalized human chondrocyte cell line C28/I2 was seeded on top of the scaffolds to assess the effect of the fibrous alignment on chondrocyte behaviour. Chondrocyte-seeded scaffolds were then cultured for 28 days, and then chondrocyte morphology, metabolic activity and viability were evaluated.

The 3D multi-layered aligned matrices were successfully fabricated using two programmed alignments: a donut-like architecture (Figure 1A) and a star-like architecture (Figure 1B), both possessing high-fidelity to the programmed alignment input. The *in vitro* studies revealed that chondrocytes adhered well to the surface of these architectures, mimicking the fibre alignment on which they were seeded. Furthermore, chondrocytes remained viable throughout the culture period, with only a few dead cells visible on the live/dead staining. Additionally, chondrocyte metabolic activity increased over 28 days of culture, confirming that proliferation occurred.

Overall, these results suggest that this novel electromechanically 3D electrospinning platform has great potential for the development of 3D electrospun matrices for TE applications, particularly those that require specific fibre alignments, not only to trigger specific cell responses, but also to imprint certain features to the 3D matrices, like specific mechanic behaviours.

Keywords*— *Tissue engineering; 3D electrospun scaffolds; Fibre alignment.

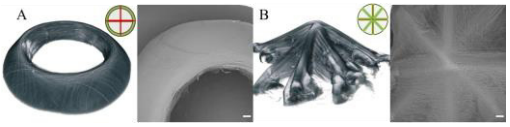

Figure 3. µCT reconstruction, programmed alignments and SEM images of the donut-like (A) and a star-like (B) 3D multi-layered aligned matrices.

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Adsorption technologies for heating or/and cooling

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***Abstract* — Due to their low environmental impact, adsorption technologies (AT) have captivated the interest of the scientific community and attracted the heating and cooling market's attention during the recent years [1]. AT are driven by thermal energy, which can be easily obtained for free from waste heat and renewable energy sources like solar and geothermal. Moreover, the fact of using natural refrigerants, such as water or ammonia, makes AT an appealing technology towards the achievement of Europe's objective for zero greenhouse gases emissions by 2050. Even if the coefficients of performance of adsorption heaters or coolers seem to be too low, they are not so low when fairly compared with the ones of the compression vapor heaters or coolers. This work reports AT suitable for heating or/and cooling, focusing on the design, development of detailed physical models and numerical simulation tools for performance evaluation and control strategies planning. A lack of detailed models considering the whole adsorption system has been identified as a major gap in literature. Physical model's space dimensionality and grid independence studies were carried out using a lumped parameter model (0D), 1D (radial direction) and 2D (radial and longitudinal directions) distributed parameter models, to describe the dynamics of the adsorber of an adsorption heat pump (AHP) [2]. A comparison and sensibility analysis of the 0D, 1D and 2D models were also presented, considering variations of some key parameters, and analyzing results' deviation taking the 2D model as the reference. The investigation concluded that a 2D distributed parameter model must be used in order to more accurately describe the dynamics of adsorption systems and provides insights on the minimum spatial resolution of the adsorbent bed that must be used to provide more accurate analyses and performance predictions. The physical models were implemented to investigate the influence of several governing parameters on the AHP's performance, more specifically on its coefficient of performance (COP) and specific heating power (SHP) [3]. The analyzed key parameters are the regeneration, condenser and evaporator temperatures, the heat transfer fluid velocity, the heat transfer fluid tube diameter, the adsorbent bed thickness, the metal-adsorbent heat transfer coefficient, and the cycle time. AT can also be used for cooling applications such as refrigeration, space cooling, chillers, and industrial process cooling. The ability to provide the cooling effect using thermal energy, which is commonly mostly available when more cooling is required, makes adsorption cooling an interesting and promising technology for that purpose. An investigation on the influence of the key governing parameters of a coated tube adsorber for adsorption cooling on the COP and specific cooling power (SCP) was carried out [4]. These studies conclude that the optimal balance between the COP and SCP/SHP must be found for each particular adsorption system, as there is a trade-off between these two performance parameters.**

Keywords — Adsorption technology; Adsorption heat pump; Adsorption cooling; Adsorption systems' performance.

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Predictive control strategies to improve temperature stabilization of tankless water heaters

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***Abstract*— The energy consumption of a building includes all the energy needed for space heating, cooling, lighting, and production of domestic hot water. Domestic hot water production accounts for 14.8% of total energy consumption in the residential sector, in the European Union [1]. The most widely used devices for domestic hot water production are tankless gas water heaters (TGWHs). They have a few advantages over other devices, such as smaller size, continuous water flow, longer life, and lower energy consumption. However, one of its drawbacks is the difficulty in ensuring the stability of the hot water temperature when changes in water flow occur. These unpredictable changes are usually very fast and severely affect the user's comfort perception. In addition, the system has its thermal inertia, the heating devices have inherent response delays and the dynamics, thermal and fluidic, are interconnected and nonlinear [2]. Traditional controllers, such as PID, can't anticipate the effects of sudden changes in water flow rate and cannot respond promptly. Newer and more advanced devices use gas modulating actuators, flow and temperature sensors and control units with feedback controllers. However, it is necessary a faster and more robust control [3]. The most promising approach to improving temperature stabilization of instantaneous water heaters is model predictive control (MPC). This advanced control technique is used in numerous applications and can increase safety and comfort indicators.**

In this work, linear and adaptive MPC is developed for water temperature stabilization. The system was modelled using a lumped space approach to model the heat cell and the output valve. They are implemented in MATLAB/Simulink platform considering a control volume where mass and energy conservation equations are established. The heat cell was modelled using a semi-empirical nonlinear model with input and output delays. The input delay comes from the heat energy delivery. The time-varying output delay is inversely proportional to the flow rate of water circulating in the heat exchanger. A comparison was made between the predictive controllers with the feedforward PID controller, commonly used by TGWHs manufacturers', and two more conventional controllers, Proportional and PID. The simulations showed that the MPC has very satisfactory results in temperature control over the other strategies. However, the use of the adaptive function enabled superior performance in temperature stabilization. This is due to the adaptive model presenting a new linear model at each time step as the operating conditions change [4]. It is able to perform the linearization of the model to the required flow rate and setpoint, at each time step. The classic MPC, since it uses a constant model, exhibits larger discrepancies when the operating conditions move away from the linearization point.

One of the manufacturers' requirements is that the control algorithms be implemented in low-cost microcontrollers, which have limited computational and memory resources. Thus, the next steps in this work aim to develop simplified techniques for implementing MPC and adaptive MPC controllers in low-cost hardware.

Keywords— domestic hot water; tankless gas water heaters; predictive control strategies; adaptive control; low-cost embedded control.

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Electrochemical reactors for sustainable ammonia production

Development of a new category of materials with enhanced electrocatalytic activity

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Abstract— A principal aim of the EU 2030 climate & energy framework is the reduction of CO2 emissions by the development of new technologies for industries and processes [1]. There is an urgent need for transitioning to a green economy, where the fabrication of sustainable chemicals is deeply urged [2]. In this regard, ammonia (NH3) is a key chemical that is produced in vast quantities worldwide as a precursor in a range of products that are vital to society, such as fertilizers and medicines. Nonetheless, its current industrial production (Haber-Bosch method) requires high temperatures and pressures, producing large quantities of CO2 due to its continued reliance on H2 from natural gas [3]. New green concepts for NH3 production are, therefore, urgently needed.

The current study proposes a highly attractive alternative to mitigate this problem, based on the electrochemical synthesis of NH3 directly from steam (H2O) and N2, using a Proton Ceramic Electrochemical Cell (PCEC), with the input of renewable electricity. However, previous reports on this concept are scarce. The studies that do exist have shown low Faradaic efficiencies and low ammonia formation rates [3], due to the lack of properly designed electrocatalysts for the nitrogen reduction reaction, with insufficient selectivity offered for the desired NH3 product. Hence, electrocatalyst design is highlighted to be a critical step to develop this PCEC concept to a more mature stage.

Therefore, the current analysis aims to develop new electrocatalyst materials based on transition metal (oxy)nitrides, which can provide one of the highest NH3 formation rates reported so far (10-9 mol cm-2 s-1). The main outcomes of this study are related to: i) kinetic studies of the stability of the new electrocatalysts; ii) fabrication of new electrochemical cells made of proton-conducting ceramics and novel (oxy)nitrides; iii) electrochemical conversion tested in a laboratorial prototype.

Work is being performed by the local team, experts in proton ceramics, with collaboration with two foreign institutions (Instituto de Cerámica e Vídrio, CSIC (Spain), experts in crystallography, and Federal University of Paraíba (Brazil), experts in materials preparation, and one of the main National chemical companies (Bondalti), experts in electrochemical synthesis, providing the required skillset to accomplish the established targets. This project offers a highly promising and potentially disruptive route to synthesize one of the most important chemicals extensively used worldwide.

Keywords— Proton Ceramic Electrochemical Cell (PCEC); ammonia (NH_3); electrocatalyst.

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3D anisotropic scaffolds for tissue regeneration

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Abstract— Numerous tissues in the human body, including the spinal cord, peripheral nerves, skeletal muscle, tendons, ligaments, cartilage, and bone, have anisotropic microarchitectures as a result of the alignment of extracellular matrix (ECM) constituents and cells that are required for the performance of direction-dependent tissue-specific physiological functions. [1] Regrettably, the demand for organ repair and transplantation far exceeds available therapies and donors. Tissue engineering (TE) provides an opportunity to combine biomaterials and microfabrication techniques to create scaffolds that mimic the aligned topographical cues of targeted native tissues with the goal of guiding exogenous or endogenous cells to secrete their own ECM, thereby generating an anisotropic neotissue and restoring its physiological function. [2]

The purpose of this communication is to discuss the fabrication of scaffolds with certain morphological characteristics that imitate the ultimate tissue to be mimicked. We are fabricating scaffolds with vertically oriented pores using an ice-templating approach. By adjusting several parameters such as the freezing rate, the freezing agent, the solid loading structure, the concentration, and chemistry of the solution/suspension, the structural features of these scaffolds can be tuned to match the ECM of multiple tissues. More specifically, to create anisotropic scaffolds, a photopolymerizable platelet lysates hydrogel, a complete xeno-free solution and a significant source of growth factors and proteins, is coupled with graphene-based materials. At the moment, we are investigating the scaffolds' potential to direct adipose stem cells and stimulate their spontaneous differentiation into osteoblastic cells for bone TE.

Keywords— Tissue engineering; Scaffold; Anisotropy; Graphene; Platelet lysates

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Modeling the performance of Phase Change Materials for Cold Energy Storage: Two different approaches

CFD Numerical Simulation and Thermal-Electrical Analogy supported by Experimental Tests

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***Abstract*— The use of renewable energy sources and the emergence of smart grids are at the forefront of fighting climate changes. To fully deploy their potential, a distributed network of energy-storage facilities is required. Integration into refrigeration facilities of enhanced energy-storage potential through techniques such as phase change materials (PCMs) to increase energy efficiency and reduce operational costs will be an important energy efficiency breakthrough [1]. When simulating heat transfer behavior of PCMs, enthalpy-porosity approach, a fixed grid model, is widely used on CFD models through software tools such as ANSYS-Fluent [2]. A pseudo porous region with a given porosity value ranging from 0 to 1 is considered to attenuate the problem of accounting for the zero-velocity condition when material solidifies. However, the proper selection of the numerical value to consider as mushy zone parameter (Amush), which varies from 10^3 to 10^8, is critical to account for natural convection [3]. On the other hand, electrical-thermal analogy is a technique used for developing dynamic models of home refrigerators [4].**

Two different approaches for predicting the behavior of PCMs were hence taken to evaluate: 1) The importance of mushy zone parameter (Amush) on Numerical CFD investigations to the phase change behavior of low temperature thermal storage materials; 2) The accuracy of developing an Electrical Circuit equivalent to the Thermal system under research including the use of PCMs on a common Vapour Compression Refrigeration System. Experimental tests with two cylindrical recipients and three different PCMs (water, NH4Cl+H2O eutectic and NaCl+H2O eutectic) were performed to validate the results. The main results show that 1) The accurate value to input as Mushy Zone Parameter is widely dependent on the viscosity of the material and geometrical parameters of the enclosure, while these impact the formation of natural convection processes. Further experiments for different geometries and for cold storage materials are required; 2) Global Heat Transfer Coefficients through the Phase Change process of a cylindrical enclosure can be estimated with an overall accuracy above 80% for both sensible and latent stages through an analogue electrical circuit.

Keywords — Phase Change Materials; Computational Fluid Dynamics; Thermal Energy Storage; Modeling and Numerical Simulation; Thermal-Electrical Analogy.

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Improving the Sustainability of Heavy-Duty Transport through Enhanced Thermoelectric Generators

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Abstract— Long haul heavy duty transport accounts for a significant portion of worldwide fossil fuel consumption and greenhouse Gas (GHG) emissions. The Heavy Duty Vehicles (HDVs) performing these trips are expected to be last in their transition towards total powertrain electrification [1]. their increasing degree of hybridization and typically high onboard electric consumption demand makes the electric conversion of a portion of the heat lost through their exhaust especially attractive for their sustainability [2]. Long haul trips with HDVs have a good recovery potential because these trips are often made almost entirely under high engine load [2]. Thermoelectric generators (TEGs) are able to convert exhaust heat into electricity without moving parts and thus, with little to no maintenance needs [3]. The authors have been exploring new affordable and performing thermoelectric materials [4], as well as methods for maximizing exhaust energy absorption under highly variable engine loads while delivering this thermal energy at a precise temperature range to optimize TEG output irrespective of engine load [5], [6]. This is done by incorporating a liquid-to-vapour phase change medium that provides a uniform heat source temperature for the TEG devices. The present study assesses the merit of incorporating an Exhaust Thermoelectric Generator (TEG) using wavy fins and variable conductance vapour chambers to HDVs performing long haul trips. The Simulations were performed with AVL Cruise in conjunction with a model developed by the authors for the temperature controlled TEG concept [5]. The low performance typically found in previous HDV TEG prototypes seems to have been overcome due to the high ratio of exhaust heat absorbed and the optimized temperature level achieved at the hot face of the TEGs even under variable engine load conditions. This concept, along with the new generation of affordable and performing thermoelectric materials might finally render HDV TEGs a viable option for onboard electricity production.

Keywords— Fuel consumption reduction, Waste heat recovery, Thermoeletric generators, Thermal control, Variable conductance Vapour chambers.

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Reversible electrodialysis for salinity gradient power

Harvesting a non-intermittent clean renewable source

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Abstract — The energy demand worldwide has been increasing in the last decades due to population growth and rising living standards in emerging countries. Modern day human lifestyle relies on the energy produced from fossil fuels, whose resources are fast depleting. The global dependence on large amounts of fossil and nuclear fuels represents a serious environmental and geopolitical threat. The rising concerns on the impacts of greenhouse gas emissions and global warming is forcing the world to search for alternative clean and green energy resources [1].

The salinity difference between sea and river water has an available energy that is comparable to the energy produced by a 280 meters high dam. In theory, one could extract 0.8 kilowatts per cubic meter of fresh water. The amount of fresh water running to the sea in the world's estuaries, has been predicted to allow harnessing 980 GW of electric power. An additional 18 GW could be obtained by the wastewater released in the ocean [1].

Reverse electrodialysis (RED) is a non-polluting, sustainable technology, used to produce energy by mixing water streams with different salinity. RED is a non-intermittent electrochemical process that uses ion-exchange membranes (IEMs) to directly draw electric power from the flow of ions. Ions are driven to balance concentration across a selective permeable IEM, building an electric voltage called Donnan potential. This potential across the membrane results from equilibrium between the chemical potentials for the ion crossing in each direction and is proportional to the concentration gradient and membrane permselectivity. The device voltage will be the sum of the Donnan potential of each membrane stacked alternating cation exchange membrane (CEM) with anion exchange membrane (AEM) in between chambers of high and low salinity solution chambers for salinity gradient. Ion transport via inert electrodes is converted to electrical energy by a reversible redox reaction [2].

RED can be used directly for energy conversion or combined with other technologies like, desalination and water treatment. The RED application can have a positive environmental contribution while improving electric conversion power density [3].

This project results from a cooperation protocol between IPDJ - Instituto Português do Desporto e Juventude, I.P and Universidade de Aveiro, after an environmental sustainability award winning idea. The main outcome from this project will be to build a laboratorial demonstration prototype that will be presented to the IPDJ and the Câmara Municipal de Aveiro.

Keywords— Salinity gardient energy; Energy conversion; Ion-exchange membrane; Donnan potential; Renewable energy.

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Optimising anodes for high temperature electrolysis

A misfit-layered structure as a highly promising anode for solid oxide electrolysis cells

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***Abstract*— Given the increasing interest in H_2 technology in parallel with the growing concern for the preservation of the environment, the electrolysis of steam is an efficient option to provide H_2 with high purity. In this regard, solid oxide electrolysis cells (SOECs) can be applied to convert the electrical energy from intermittent energy sources (solar power and wind power) during off-peak hours, where waste heat can also be used as a substantial part of the required energy in the water splitting process, lowering the electrical demand. One of the main challenges in this mode of operation is related to the anode, which may experience rapid performance decay with delamination at the electrolyte/electrode interface caused by oxygen evolution [1]. Therefore, new oxygen electrode materials are of urgent interest, particularly those with mixed conducting properties (mixed ionic-electronic conductors - MIECs).**

The misfit Ca-cobaltite compound $[Ca_2CoO_{3-\delta}]_q[CoO_2]$, where q is ~0.62 (known as "$Ca_3Co_4O_9$" – C349), is a promising electrode for solid oxide cells operating at high temperatures due to its excellent mechanical compatibility with traditional electrolytes and its good mixed ionic and electronic conductivity under operating conditions [2]. The C349 compound is widely studied as a cathode material for solid oxide fuel cells (SOFCs), however thermodynamic studies demonstrate that its stability limit decreases towards less oxidising conditions, which is a barrier to its application in fuel cells during the oxygen reduction reaction (ORR). On the other hand, the predicted stability limit increases towards higher oxygen partial pressures, which envisages a wider potential of the misfit C349 ceramics as potential SOEC anodes for the oxygen evolution reaction (OER) [2]. Nonetheless, low oxygen ion diffusion limits its electrochemical performance [3].

In the current work, gadolinium doped ceria (GDC), a well-known ionic conductor, is used in a composite matrix with C349 to extend the region where the reaction of oxygen evolution occurs. A three-probe cell configuration is analysed by impedance spectroscopy (IS) as a function of applied anodic polarisation (DC current) in the temperature range 550 – 700 °C.

We observe that the total polarisation resistance of the C349 electrode decreases by at least 4.5 times with the addition of GDC (with zero applied DC potential). A beneficial effect of anodic polarisation is observed for the C349 electrode and the C349-GDC composite electrode, with an improvement factor of 85 % and 57 %, respectively, when applying 300 mV, highlighting the potential of C349-based electrodes as anodes for SOECs.

A short-term stability test of the C349-GDC anode at 300mV and 700 °C exhibits a stable response with a current density of ~120 mA cm^{-2}, suggesting its durability under SOEC conditions. Microstructural characterisation after the tests shows that the C349-GDC electrode is a very promising SOEC anode, with no noticeable degradation for more than 50 h. These successful outcomes are explained by the good chemical and thermo-mechanical compatibility of C349 with the GDC phase, in addition to the better sinterability of the latter phase.

Keywords*— Calcium cobaltite, impedance spectroscopy, anodic polarisation, solid oxide electrolysis cell (SOEC).

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On the refrigerant compressor suction conditions

From the dry to the wet suction

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Abstract— Superheated or, in the limit, saturated vapor at the compressor suction inlet is an essential condition for the analysis and design of the common vapor compression cycles (VCC) used in refrigeration (R), heat pumps (HP), and air-conditioning (AC) systems. Frequently, to prevent liquid slugging in the compressor, thermostatic expansion valves are sized for superheating degrees of the order of 5 K, and low-pressure accumulators are installed to retain the excess and/or non-evaporated refrigerant in the suction line. Other devices, such as internal heat exchangers, are also used for compressor protection, owing to the high damaging potential of the liquid refrigerant in its moving parts. Liquid incompressibility and consequent liquid entrapment or the lubrication oil washing effect are the main hazards.

However, can this be a universal truth? What about the liquid refrigerant injection in the compression pocket (a recurrent strategy for reducing the discharge superheat and compression work)? And the dynamics during the starting-up period or associated to the reduction of the evaporator's heat exchange capacity under low-temperature environmental conditions, particularly observed in HP water heaters (HPWH)? In fact, circumstances exist for which large amounts of liquid refrigerant might flow into the compressor even when all precautions are taken. The answer relies on the compressor type and purpose of the (un)intentional liquid refrigerant admission.

With fewer moving parts, rotary compressors are more robust than those from the reciprocating type. Actually, scroll and rolling piston compressors are less sensitive to wet compression and slugging problems. In the last decades, compressors technology evolved significantly, facing challenges in energy efficiency and accommodating new refrigerants due to environmental issues. With the arrival of R32, a mildly flammable (A2L) low-GWP HFC refrigerant, several researchers and compressors manufacturers designed different control strategies to reduce the discharge temperature and, therefore, the flammability hazards. Among these strategies, based on wet suction conditions, the liquid refrigerant injection and the wet (two-phase) suction methods were the most relevant ones, allowing higher performance results. The liquid refrigerant injection is the most widely used in R32 HP and AC units driven by rotary compressors and controlled by electronic expansion valves [1]. Some R32 compressors can handle vapor qualities as lower as 0.75 without deteriorating the system's reliability and performance, substantially reducing the discharge temperature [1]. Other researchers reported the improvements in CO2 scroll compressors to deal with the unsteady and steady return of liquid refrigerant in accumulator-less HPWH during the starting-up and reduction of the evaporating capacity, respectively [2]. Their features enable a constant heating capacity even under extreme environmental conditions (subzero air temperatures). Under wet compression conditions, the refrigerant specific volume decreases as the vapor quality decreases, increasing the mass flowrate and proportionally augmenting the heat transfer rate in the high-pressure-side heat exchanger.

Undoubtedly, the paradigm has changed. Applying the commonly used approach under these conditions, i.e., assuming dry suction, can originate abnormal or physically non-realistic isentropic efficiencies. Thus, the analysis and design of equipment using VCC may have to consider also wet compression conditions.

Keywords— Compressor, Wet suction, Isentropic efficiency.

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Coupling reduced graphene oxide with a decellularized extracellular matrix as a regulating microenvironment for the spinal cord injury

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Abstract— Each year worldwide, 250,000 to 500,000 people suffer from a spinal cord injury (SCI). Due to the severely limited ability of the central nervous system for self-repair, most of the consequences on mobility and physiological functions last for a lifetime. Although the clinical management of SCI has improved some functional outcomes, a regenerative strategy for SCI repair is yet to engineer [1].

The NeuroStimSpinal project aims at designing a novel regenerative strategy to repair the SCI, relying on innovative graphene-based scaffolds coupled with an in situ electrical stimulation.

The innovative scaffolding strategies resort to graphene-based materials such as reduced graphene oxide (rGO) supported by a decellularized extracellular matrix from the adipose tissue (adECM), a uniquely abundant and easily accessible source of native-like architecture and biochemical framework. We investigate how rGO interfaces with adECM to manufacture scaffolds that translate into a regulating microenvironment for the key players of the neural tissue, such as neural stem cells and astrocytes. By limiting the extent of reduction in rGO and approaching it as a supramolecular physical crosslinker, scaffolds with high rGO loadings (up to 50 wt.%) were manufactured. The increasing rGO phase within the scaffolds imparted to the scaffolds a higher water uptake capacity and induced a macroscopic softening.

Regarding the neural cell response, high rGO content appreciably directed the stem cell fate by guiding their differentiation towards neurons rather than astrocytes. Interestingly, primary astrocytes fate was also modulated by increasing rGO content within the scaffolds. While the expression of scar-forming markers, associated with the deleterious glial scar, were not induced, increasing rGO boosted the expression of reactivity markers, associated to the reactive astrocytes, known to support neuronal function and axonal growth. Ultimately, the adECM:rGO scaffolds display promising biochemical and biophysical features to differentiate neural stem cells while simultaneously prompting reactive astrocytes to act collaboratively towards the spinal cord injury repair.

Keywords— rGO, neural stem cells, astrocytes reactivity.

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Engineering dynamic microenvironments in tumor models

Tumor-on-a-Chip (ToC)

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Abstract—Tumor-on-a-Chip (ToC) technology aspires to be an effective solution to develop patient-specific tumor models capable of addressing fundamental studies of tumor tissue properties and becoming the state-of-the-art diagnostic tool and drug screening platform. To achieve these goals the engineered tissue must accurately replicate organ-level tumor activities. The biomimetic tumor tissue microenvironment combines several components, such as multiple cell types, extracellular matrix (ECM) and vasculature, all with a complex and precise spatiotemporal distribution. The fabrication of a construct with all these components combined with tumor's biomechanical and physiological cues has been challenging the scientific community.

Early stage ToCs have been produced primarily utilizing conventional microfabrication techniques, which frequently are not adaptable to biological architectures. On the other hand, additive manufacturing (AM) has the capability of depositing cells, biomolecules and biomaterials with precise spatial distribution in a layer-by-layer fashion [1]. The integration of microfluidics with AM potentiates the precise spatial distribution of 3D cellular architectures within microfluidic devices.

This work aims at integrating a microfluidic channel with an AM fabricated complex microchannel embedded in an ECM mimicking material. A protocol for the fabrication of pre-vascularized construct containing multicellular tissues is being developed. The flow of media in the system will be admitted by the microfluidic channels which will be coupled with the channels integrated in the construct. The fabrication of the integrated channels is done by using a sacrificial biomaterial as a mold and casting the ECM mimicking material over it. Gelatin methacryloyl (GelMA) is polymerized by stereolithography to produce a mold defining the precise architecture of the vascular mimicking channels. The GelMA mold is introduced in the microfluidic device and a collagen solution is casted over the mold. The device is incubated at 37°C. Leaving it overnight at this temperature will result in collagen polymerization and in the dissolution of the GelMA mold. The dissolved GelMA can be removed by flowing media through the microfluidic system resulting in a collagen construct with hollow complex channels. This integration of microfluidics with AM allows for a more sophisticated and effective simulation of the vascular architecture and physiology of solid tumors.

Keywords— nanotechnology; 3D bioprinting; tumor-on-chip; microfabrication.

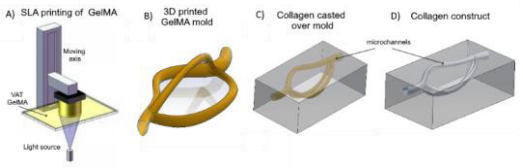

Fig.1 – Fabrication of hollow microchannels containing collagen construct. A) Stereolithography printing of microchannels mold. B) 3D CAD of the microchannels mold. C) Casting of collagen. D) Collagen construct after polymerization and flushing of sacrificial material.

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Self-adaptive instrumented electromagnetic generator

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***Abstract*— Motion-driven electromagnetic energy harvesters are widely used to power both small-scale and large-scale devices as well as suitable to operate as self-powering technologies, allowing customizable upscaling and downscaling, ensuring low production and maintenance costs, and even able to integrate with hybrid solutions [1,2]. Remote sensors and/or actuators, mobile devices, portable and wearable systems, and intracorporeal biomedical devices are some examples of using self-powering technologies for ever-increasing small-scale harvesters. Many relevant advances have been carried out in renewable energy systems regarding the scope of large-scale powering. Even so, they are not enough to overcome the limitations of intermittency of some renewable sources, such as wind and sun, and/or the significant time-varying mechanical excitations provided by wind and ocean energy, among other sources. If energy sources are intermittent, energy production costs are high, as complex grid management, expensive energy transduction mechanisms and energy storage systems are required [1].**

This work focuses on self-adaptability: so that their architectures can be automatically tuned to optimize the harvester length as a function of time-varying external power source dynamics driving the harvesters. This feature is of utmost importance as these electromagnetic harvesters exhibit highly nonlinear behaviors with resonant (excitation frequency matching the natural harvester resonance frequency) and hysteretic dynamics [1,2].

A model based on first principles was developed and experimentally validated. Self-adaptability was realized by changing the generator's length and natural frequency as a function of the mechanical excitation characteristics. We propose an instrumented electromagnetic generator for optimized self-adaptive performance. Instrumentation comprises: (i) an accelerometer to monitor the mechanical excitations driving the harvester; (ii) a stepper motor to change the harvester length by changing the distance between non-levitating magnets; (iii) a processing system with a microcontroller and conditioning circuitry to manage and control the entire system. The ability of the self-adapting generator to provide significant power gains were both theoretically and experimentally demonstrated. Although this generator exhibits a volume of 140.7 cm^3, maximum open-circuit resonant voltage peak values up to ≈500 V, short-circuit current peaks of 36.5 mA and average powers of 1.5 W (with instantaneous power peaks up to 6 W) were achieved for matching loads of 10-30 kΩ under translational excitations with displacement amplitudes of 3-10 mm and frequencies of 4-18 Hz. The maximum power output was achieved under different conditions of input amplitudes and frequencies for corresponding controlled optimal loads and distances between fixed magnets. A Monte Carlo method for different case studies, considering the power consumption of instrumentation, showed the ability of the self-adaptation mechanism to provide energy gains that can surpass 30% [3]. These are very promising results that highlight the potential of self-adaptive energy harvesting technologies for opening new research directions towards the emerging of a new line of highly sophisticated autonomous generators.

Keywords*— *electromagnetic adaptive generator; magnetic levitation; energy generation; self-powering

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Cork-STF composites for crashworthiness applications

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***Abstract*— Crashworthiness is an essential characteristic for many types of safety equipment. For applications involving head protection, for instance, the use of synthetic materials such as the expanded polystyrene foam (EPS) is the norm, since it presents low density and acts as a cushion by plastically deforming at low loads, therefore limiting the transmitted force to the head. However, its permanent deformation with limited elastic recovery decreases its energy absorption capabilities, making it efficient for withstanding only one impact [1]. Cork is a natural material that presents excellent properties for applications concerning impact resistance since it can experience high levels of deformation without undergoing fracture or damage. Because of its recovery capabilities, it is a material of great interest in all applications where multi-impact energy absorption is required [1,2] and its performance can be further enhanced by combining it with other materials into composites. One promising material to be used in combination with cork is the shear thickening fluid (STF), a non-Newtonian fluid that exhibits a sudden increase in viscosity as the applied stress/strain rate increases [3]. Studies involving the use of both materials are few but their results are promising, suggesting that cork filled with STF has the potential to be used in safety paddings [4] and that the non-Newtonian fluid used as an interlaying agent between cork laminates can enhance the cork composites' impact performance [5]. This study tests several combinations of hybrid composites in layered structures involving cork laminates, different types of polymers such as polyvinyl chloride (PVC) and polyurethane (PU) containing shear thickening fluid (STF) in their composition, fabric impregnated with STF, and the fluid in bulk used as an interlaying agent. The aim is to evaluate, through a series of drop impact tests, the robustness of the composites to be applied in head protection devices used in micro-mobility. During the study, various composite structures were subject to impact tests of 20 and 100 J, deliberately lower and higher energy levels than the 69 J established by the European standard for bicycle helmets – EN1078. The authors directly compared composites of the same thickness and dimensions, determining the influence of the material supplementary to cork in the impact performance. Results are promising for two different designs: a) a solution with encapsulated STF, showing a reduction of up to 8.5% in peak acceleration and smoother deacceleration through higher deformation levels for a given amount of energy absorbed per unit volume; b) a solution with impregnated fabric, which is the lightest and less dense amongst all, displaying very good compromise between density and good impact resistance.**

Keywords*— *eco-friendly materials; traffic safety; crashworthiness

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Study on Noise and Exhaust Emissions Modelling: Kinematic-Variables Impact and Critical Hotspots

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***Abstract*— The hazardous effects of traffic noise and exhaust emissions on human health are well reported in the literature and, among the others, they involve strokes, cardiovascular problems, bronchitis, and suppression of the immune system. The minimization of noise and exhaust emissions during a trip could represent a fundamental step to mitigate the aforementioned issues, but there is a need for a correct assessment of noise and exhaust emissions in real driving conditions. The main objective of this research is to provide a methodology suitable for the evaluation of the sound power levels (L_w), and carbon dioxide (CO_2) and nitrogen oxides (NO_x) hot-emissions during a single-vehicle trip, through ad-hoc models, using speed, acceleration, and road grade as main input variables [1].**

Six passenger cars (four diesel, one gasoline, and one hybrid electric) equipped with an On-Board Diagnostic (OBD) system, were driven along one partly urban-rural and two highway routes in the central area of Portugal. Vehicle speed and acceleration, and road grade were extracted from the OBD dataset and then, used as input for seven different Noise Emission Models (NEMs) and the Vehicle Specific Power (VSP) methodology.

The first ones (which include the Lelong model, Harmonoise, Nouvelle Méthode de Prevision du Bruit – NMPB, Common Noise aSSessment methOdS – CNOSSOS, SonRoad, Acoustical Society of Japan Road Traffic Noise Model – ASJ, and Vehicle Noise Specific Power model – VNSP) were used for assessing L_w at 1 Hz frequency, from which the total and the average sound power levels ($L_{w,tot}$ and $L_{w,ave}$, respectively) [2] emitted during a trip were computed. Among the considered NEMs, only Harmonoise and NMPB models consider the acceleration as an input variable through a correction coefficient.

On the other hand, the VSP methodology was used for the estimation of the CO_2 and NO_x emissions through the adoption of specific emission factors previously calibrated for probe vehicles [3,4].

Results show that the NEMs estimated higher noise emissions along the highways, while VSP achieved higher exhaust emissions along the partly urban-rural route. This can be attributed to the fact that speed is the main input parameter in the noise estimation and drivers maintained a higher speed on the highways than the urban-rural road. On the other hand, the acceleration maneuvers on the urban/rural road affected the exhaust emission estimations through VSP, leading to an increase in its values compared to scenarios in which cruising speeds were kept. Moreover, acceleration results to be a fundamental variable for the noise evaluation mostly in the low-speed range (below 50 km/h) due to the predominance of the engine noise contribution on the rolling one. The L_w values estimated with NEMs characterized by an acceleration correction term present higher correlation coefficients with VSP than the other NEMs solely based on speed. Such noise models also fail to recognize roundabouts and other traffic singularities as critical hotspots.

Keywords*— *Noise Emission Models; Vehicle Specific Power; Kinematic Parameters; Critical Hotspots.

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Clustering driver behaviour eco-safe performance based on driving simulator experiments

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***Abstract*— Literature reveals road vehicle driving behaviour is fundamental in the evaluation of transport systems, mainly due to its complex variability [1]. This variability makes the driving behaviour study not yet fully understood, despite much research around the topic, either under real-world conditions or simulated environments [2]. In particular, unravelling driving behaviour characteristics can be essential for understanding traffic conditions and ensuring improvements in terms of fuel consumption, environmental sustainability, and safety. Simulator experiments can be a powerful tool to enable in-depth studies and collect a large amount of data, with accurate results that can be used to increase road safety and predict dangerous situations [3] [4]. Driving behaviour concerning speed and acceleration profiles significantly affects road safety, pollutant emissions, and fuel consumption. Nevertheless, if a thorough study is to be undertaken and to take a broad view of driving patterns and results, it is important to take into account other variables as well as to comprehend driving behaviour that may present deflections and variability (e.g., gear-shift strategy, acceleration style). Although there are countless studies assessing driving behaviour, only a few use driving simulators to study it, specially aggregating the stress and comfort components [5].**

In this research, several driving simulation tests (a total of 64 runs in two different scenarios on eight different days) were carried out with the help of two volunteers (male and female) driving on specific routes in both urban and highway environments. Additionally, drivers were monitored in terms of heart rate (a stress-related variable, which allowed to supplement information about the drivers and improve the effectiveness of the driver monitoring system). The collected data also involves vehicle dynamics (speed, acceleration, pedal usage, position and the adopted gear-shift strategy. After data treatment. Pollutant emissions (NOx and CO_2) were estimated microscopically using the vehicle-specific power (VSP) methodology. Eco-safe drivers' performance was assessed for each case study (city and suburban/highway) and a database was created for different segment types. For data analysis, data mining methods, particularly, clustering, was applied to obtain eco-safe profile bins considering road segments specificities. This work's primary goal is to present an integrated assessment of driving behavior. This research will contribute by providing a driver-centric assessment that can form the basis for an in-vehicle system that warns drivers about their eco-safe performance.

Keywords*— *driving behaviour; simulator; pollutant emissions; safety

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Combining Agent-Based Modeling and Life Cycle Assessment for Evaluating Shared, Automated, and Electric Mobility Systems

A Methodological Approach

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***Abstract*— Vehicle electrification, connected and automated driving, and shared mobility are expected to be a crucial part of future transportation systems and play an increasing role in the next years [1]. Although the future of Shared, Automated, and Electric Vehicles (SAEVs) imply promising perspectives in terms of both social-economic and environmental aspects, there is still scientific uncertainty about their real impact due to the operational efficiency strongly dependent on local spatial-temporal context.**

The environmental potential of SAEVs services has been studied in the literature, and attention has been paid to understanding the real impact of the future mobility systems. For instance, Vilaça et al. [2] evaluated the SAEVs' services through a life-cycle assessment methodology, finding that SAEVs mobility yield the potential to reduce up to 42% of the environmental impacts when compared to privately-owned AEVs. It was also verified that the impact categories with a higher potential for reduction are human toxicity, mineral resource scarcity, and ecotoxicity. The reported study has covered a notable lack of assessing the environmental impacts of SAEVs mobility systems from a life cycle perspective. However, the study was applied to an optimally designed fleet, considering that all the demand is served by the SAEV mobility service. In fact, understanding the transformative influence of SAEVs in transportation systems and, particularly, on users' mobility patterns is itself an important research gap.

This work intends to report a methodological approach capable to fulfill the above-mentioned limitations. The application of an agent-based simulation model based on the actual individual mobility preferences and behaviors aims to design the future SAEVs fleets and identify the emerging effects of SAEVs services to dynamically evaluate their life-cycle impacts. The main advantages expected from coupling both methodologies consist in reducing the uncertainties related to the operational phase of SAEVs and contributing to a behavior-driven life-cycle assessment approach.

***Keywords*— Automated and Electric Vehicles (AEVs); Shared Mobility; Agent-Based Modeling; Life Cycle Assessment.**

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Integrating the Water-Energy Nexus in Water Supply Systems Optimization

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Abstract — Water supply systems (WSS) are intensive energy demanding infrastructures that rely on water storage tanks and pumping systems for delivering water to consumers. Due to the current challenges facing the water sector, improving the operational efficiency of WSS is paramount. The ongoing energy transition, namely in the power sector, offers opportunities for water utilities to provide demand-side management with mutual benefits for both sectors [1]–[4]. In addition, current investments in renewable energy sources by water utilities reduce its dependence of energy price fluctuations. These opportunities increase the available resources to be managed and appropriate tools to support decision making are essential to assist operating WSS more efficiently [5], [6]. Therefore, a major challenge lies in finding operation strategies that can reduce energy costs in WSS while satisfying the consumers' demand in terms of water flow and pressure.

The aim of this work is to present preliminary results of the review and systematization of operational control strategies to reduce energy and costs in WSS. For this purpose, we explore: (i) participation in demand response mechanisms, (ii) increasing energy efficiency using variable-speed pumps, and (iii) the utilization of local renewable energy sources. This work also addresses the importance of decision support tools to promote the integrated management of resources and thus increase the WSS efficiency. Despite the major advances in the area, research gaps have been identified such as the need for the development of optimization models that consider the full integration of available resources to improve the real-time operation of WSS, as well as the use of forecasting tools. Furthermore, research on the application of optimization techniques to more complex water networks and extended analysis periods is scarce.

Keywords — Water supply systems; Operational control optimization; Decision support tools.

ACKNOWLEGEMENTS

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Remote Monitoring Platform for evaluating vehicles parameters and road interactions

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***Abstract*— With the evolution of the Internet of Things (IoT), like in different areas, the Automotive Industry had to adapt to the Internet of Vehicles (IoV). Consequently, the number of electronic systems and devices in an automobile is ever increasing. On one hand, there is a growing tendency of using these technologies to improve road safety, by decreasing the probability of human error. On the other hand, to guarantee the safety and proper function in the operation of vehicles it becomes necessary to acquire information and monitor these devices, to determine the cause of failures that may happen and of the equipment wear to prevent malfunctions and accidents. [1][3]**

This work is created with the purpose of enhancing the driver's awareness of the surroundings of the vehicle and alert of malfunctions and anomalies that might happen to the car. Therefore, helping to prevent risk situations and increase road safety. With that in mind, this work will have two branches. First, a program will be created to read the data from the vehicle's diagnostic system by the monitoring of the engine's working parameters, such as speed, engine's rpm, or error codes. With this analysis it will be possible to define the normal driving conditions to determine when some problem or malfunction occurs before it can evolve into some serious issue. All the while, on the other branch, LiDAR sensors and a GPS will be installed in the car that will be used for object detection of the possible obstacles that the vehicle may come across in normal road conditions, be it another vehicle, a person, or objects. The readings acquired will be stored in a database in real time for analysis and treatment to get the desired information from them. Also, the information should be easily accessible and displayed to the user on a web page, so it can be consulted through any device with a Web Browser and internet connection. Therefore, with this work drivers would be assisted with the awareness of the vehicle's surroundings and be able to monitor the vehicle's proper function and discover if problems should appear before it could cause major failures and safety breaches. [4][5]

This work is developed as part of the PAC – Portugal AutoCluster for the Future project, which unites concrete research and development actions in the automobile industry to contribute to a vehicle of the future, generating "know how" around sustainable mobility and green economy. This project associates universities, investigation centers and companies within the automobile industry. As University of Aveiro is inserted in the research branch PPS4 – Cooperative, connected, and automated vehicles, this work is integrated into this branch, working for the automatization of the vehicle, in order to make it more efficient and safer. [2]

Keywords— Vehicle Monitoring; Object Detection; ECU, LiDAR, Intelligent Vehicles.

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Reliability Analysis of a Driving Simulator to Reproduce Vehicle Dynamics from a Microscopic Point of View

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Abstract— Road transport has gradually become more essential over the years. Despite the constant technological innovation, the sector remains a significant source of pollutant emissions. Studies show driving behaviour plays a crucial role in such impacts and that it is essential to understand driving style characteristics better to implement pollutant emissions mitigating measures [1]. Research on solutions to increase the sustainability of vehicles and reduce their emissions is a timely topic. Although real-world experiments can be conducted, these entail some issues, especially regarding the risk of a crash. Thus, simulator experiments can be considered a relevant way to study vehicle dynamics and driver behaviour. Driving simulators can reproduce the driving experience realistically, presenting the users with visual, audible, and kinematic information [2]. Most driving simulator studies focus on a risk assessment; however, if the simulation results are unreliable in terms of accuracy considering real-driving conditions, the scientific usefulness and robustness are severely compromised.

The present research aims to study the reliability of a fixed-based driving simulator to reproduce accurate driving parameters for emission estimation. For that, several tests on a driving simulator were conducted for both urban and highway environment scenarios. Additionally, using probe vehicles equipped with ODB devices, real-world experiments in similar road segments and routes were carried out. The collected data on both monitoring experiments involved vehicle dynamic parameters, such as instantaneous speed, acceleration, and position. The pollutant emissions were estimated by applying the Vehicle Specific Power (VSP) methodology. A comparative evaluation approach was conducted to validate the obtained results and, therefore, assess the reliability of a driving simulator in reproducing vehicle dynamics and emissions. The developed work can be relevant for showing the capability and robustness of simulator experiments for a comprehensive driver behaviour analysis: the relation between driving style and pollution.

Keywords— driving simulator; emission models; reliability; validation.

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Energetic and environmental analysis and efficiency optimisation of a public transport corridor

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Abstract— Nowadays, the transport sector is one of the main ones responsible for emissions and energy consumption [1]. The European Union has a major goal, besides improving the citizens' quality of life, to transform its economy into the first climate-neutral economy, and for that, sustainable urban mobility should be promoted [2], [3]. In addition to other initiatives, this type of strategy is focused on promoting an efficient public transport system that allows the reduction of the use of private vehicles, minimizes traffic noise and air pollution, and enables good levels of accessibility to citizens [4]. However, public transport systems need to adapt periodically to the development of the urban and peri-urban context in which they operate and to behavioral changes in mobility habits following disrupting experiences such as, for example, the Covid-19 pandemic. This research aims to promote new technologies and strategies to increase the efficiency, safety, and quality of public transport systems by studying and promoting new and sustainable regional policies. Regional energy-environmental characterization of a public transport corridor in Aveiro that includes the AveiroBus's road line 04 and the Vouga's railway line will be studied to evaluate alternatives that bring more efficiency and sustainability to the connections at various levels. The work involves three main phases – a) empirical data collection for supply and demand characterization based on GPS data on vehicle dynamics, passenger counts and passenger surveys; b) assessment of operational and environmental performance through modelling tools, c) Key performance indicator analysis, identification of problems and inefficiencies and study of alternative strategies. One of the main goals of the optimization phase is to improve interconnectivity between rail and road and evaluate the possibility of introducing alternative, more efficient modes in certain parts of the corridor. The presentation will summarize the preliminary conclusions of the ongoing research, namely energy performance indicators per passenger along the different routes analyzed in diesel buses and trains.

Keywords— Urban mobility, Public transport, Environment, Emissions, Sustainability,

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Towards energy sustainability and cost reduction of water supply systems through operational optimization methodologies

A comparative study of problem formulations

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Abstract—Energy efficiency plays a major role in the sustainability of water utilities since 35% of the total expenses with water production are being spent on energy. In 2030 the water demand will be higher than 30 years before and is predicted to increase by 55% worldwide by 2050 [1], and this means an even higher energy consumption. This high energy consumption makes energy efficiency a critical factor in the sustainability of water management entities, promoting the adoption of intelligent solutions capable of reducing costs.

The operation of Water Supply Systems (WSS) is typically guided by rules that aim to meet multiple and competing objectives, such as minimizing operational cost, energy use, and flood risk, and maximizing water quality [2]. Therefore, optimization has several areas where it can be applied in WSS. In the literature, there are three main applications areas: Pump operation, water quality, and valve control. However, pump operation is the most critical one.

To successfully supply water with adequate pressure to consumers at demand nodes representing a significant amount of operation and maintenance (direct) costs. Increasing energy costs for pumping and water demands have made water authorities urgently seek methodologies that can maximize cost savings while satisfying system performance criteria. Adjusting pumping times to cheaper tariffs and using variable-speed pumps are some possible solutions. However, their combination is not easy, being this even humanly impossible. In addition, constraints must be respected, especially the satisfaction of customers' water requirements, pressure, and water quality.

Several researchers have been developing techniques for this problem applying linear, nonlinear, dynamic programming, and heuristic optimization methods [3]. Nonetheless, the efficiency of the operational control can be improved directly through its mathematical formulation. When solving real-world problems, mathematical (optimization) models become more complex, since the number of decision variables and constraints are generally larger and, the objectives more challenging. In the literature, several mathematical formulations for this optimization problem exist, however, the most efficient/robust formulation is still an open question.

When solving real-world problems, problem formulation becomes more complex, as the number and type of decision variables and objectives are generally larger. The selection and numerical specification of the most appropriate decision variables, constraints, and objectives become more difficult [4]. This work aims to present a literature review and a comparative study of the two most implemented WSS problem formulations.

Keywords— Sustainability; Energy efficiency; Water supply systems; Optimization methodologies;

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Urban mobility environmental effects during the COVID-19 pandemic in heterogeneous European cities

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***Abstract*— The recent COVID-19 pandemic has strongly affected social and economic activities. After the outbreak was classified as a pandemic in March 2020, the mobility patterns around the world impacted commuters' mode choice behavior, mostly due to the increased risk perception in public transport, which had a huge impact on demand [1]. Governments applied measures to tackle the spread of the virus, imposing lockdown periods and restrictions on people's movement. Studies have been focusing on analyzing a modal shift from public to individual transport [1,2], and recently, few studies evaluated some environmental impacts [3]. One would expect that a decrease in traffic volumes would lead to a proportional decrease in air pollution levels but in fact, studies show nitrogen oxides (NOx) levels decreased in many places [4], but in the expected proportion. This shows unequal observed trends regarding mobility patterns and consequent levels of pollution. On the one hand, this may be justified by people using private car and avoiding the use of public transport; on the other hand, the observed speeds may have been higher than usual due to less road traffic. For instance, a research conducted in Germany [5] with the aim of studying the adjustments in transport mode choice regarding the car, bicycle, and public transport, concluded that during a strict lockdown period, people showed preference towards the car. Additionally, people have been changing some habits, such as periods of teleworking and flexible work hours, which also yield impacts on pre-pandemic mobility patterns. These changes affect the environmental impacts of mobility. Since there is a strong need for a broader study providing an assessment of these impacts, the proposed research consists of a study of road externalities associated with different pandemic periods in a selection of heterogeneous European cities: Lisbon (Portugal), Stockholm (Sweden), and Bucharest (Romania). The specific objectives of this study are to aggregate mobility and activity data from different sources (specifically, Google and Apple mobility reports), evaluate mobility trends, and estimate the associated pollutant emissions, in particular, carbon dioxide (CO2), since it contributes to global warming and NOx, a local pollutant that may pose adverse effects to human health. For that purpose, city-related vehicle fleet compositions are considered, and the COPERT software is applied for each city-data. A comparative evaluation is performed and allowed to conclude during the periods of lockdown, a decline in CO2 emissions was observed in all cities, nevertheless at different paces, but stronger in the first lockdown. Our study highlights mobility trends are complex and the evident recent increase in private passenger transport may compromise European climate goals. Therefore, the present study is relevant to support policy strategies.**

***Keywords*— mobility impacts; COVID-19; pollutants emissions; travel behavior.**

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Head Protection for Micromobility

How Design can minimize severe head injuries

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***Abstract*— Micromobility is a topic that has been on the radar for the last few years. It marks the change to more sustainable modes of transportation and establishes solutions that fit the needs of ever-growing city centres by providing flexible, sustainable, cost-effective, and on-demand transportation alternatives. More than a quarter of the world's population lives in cities with more than one million inhabitants, and the average traffic speed in some of those cities is around 15 km/h [1]. So, it can be frustrating to travel by conventional means of transportation, such as by bus, shared or private car. In China, half of the micromobility trips in terms of dockless bike-sharing are part of multimodal trips that encompass public transportation [2] and in the United States in 2019 people took 86 million e-scooter trips, more than any other micromobility program, representing a 100% increase over the past year [3]. This exponential growth came at the cost of insufficient and inefficient laws, infrastructures, and safety measures. Several studies have shown that helmet usage among micromobility users is very limited, averaging 4%, according to the International Transport Forum (ITF) [4]. Injuries to the head and face are commonly found with e-scooter hospital admissions. Craniofacial trauma could be significantly reduced by wearing a protective helmet [5]. Some solutions like mandatory helmet legislation and folding helmets have been developed to tackle this issue but are focused on its individual aspect.**

The challenge is to develop a helmet for head protection, adapted to the specific needs of users of shared micromobility. Considering the spontaneity of use of these vehicles, issues related to the hygiene of the equipment, integration of the helmet in the structure of the e-scooter, feedback on the integrity of the helmet structure and promoting safe driving practices. Strategically, the solution to be developed will integrate eco-efficiency principles through the use of sustainable materials and production technologies with a reduced carbon footprint, in line with the Sustainable Development Goals of the United Nations 2030 Agenda.

Keywords*— *Micromobility; Sustainability; Accidents; Design; Protective equipment; Crashworthiness

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Emissions-related external costs in an intercity corridor

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***Abstract*— More than 70% of the transport-related emissions in the European Union are attributed to the road transportation [1]. In Portugal, a major contributor to the transport-related emissions are intercity trips, that account for 65% of the kilometers travelled and more than 55% of CO_2 and NO_x emissions [2].**

The main objective of this paper is to assess an intercity corridor in terms of emissions-related external costs.

The intercity corridor under study is the one between Aveiro and Coimbra, and two main road options are used, a motorway and a national road. Both road options are compared in this study. A traffic model is developed using the macroscopic traffic modelling software, PTV VISUM. To estimate the emissions, a macroscopic modelling strategy is used based on [3], and the external costs are then estimated using [4]. The population surrounding both road options is also taken into account for the local pollutants' external costs estimation.

The motorway has higher traffic volume, around 715 vehicles per hour and per way (vphw) travelling at an average speed of 118 km/h, while the national road has around 475 vphw travelling at an average speed of 79 km/h. The results are represented in the next table.

Table 1 – Emissions-related external costs regarding both road options on the intercity corridor between Aveiro and Coimbra. The results are in € per pollutant per vehicle per hour.

Route	Road	CO_2	NO_x	$PM_{2.5}$	PM_{10}	NMVOC
Aveiro - Coimbra	Motorway	0.7271	0.0624	0.0806	0.0321	0.0018
Coimbra – Aveiro	N. Road	0.7221	0.0602	0.0778	0.0309	0.0017
Aveiro – Coimbra	Motorway	0.5738	0.1255	0.1892	0.0768	0.0054
Coimbra - Aveiro	N. Road	0.5686	0.1193	0.1809	0.0734	0.0052

Regarding the total emissions-related external costs, they are 7% higher in the national road when compared with the motorway results. When looking at each pollutant, the results are higher in national road for NO_x, $PM_{2.5}$, PM_{10} and NMVOC (local pollutants), but has lower CO_2-related external costs. The average speed is lower in the national road, but it has much more population in the surroundings, which leads to higher emissions regarding the local pollutants, but lower CO_2 emissions.

In conclusion, the emissions-related external costs estimation in an intercity corridor is important and relevant, for example, when discussing road pricing strategies and should be considered to mitigate impacts from intercity trips.

***Keywords*— Intercity corridors; emissions; external costs.**

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Towards interpretable Machine Learning Hydraulic Simulation Models

A Shap Values analysis application

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Abstract— In human cultures, water supply systems are critical. Climate change and urban population growth place a greater strain on water supplies [1], affecting many aspects of modern society. At the same time, urban water networks are ageing, and rehabilitation efforts must be weighed against the expenses of expanding the network [2].

Because of the processing power available today, machine learning appears to be a magic formula for many issues, and it has now been applied to a wide range of problems, including Water Distribution Systems, smart water networks included [3]. However, because of their black box character [4], neural networks do not always provide actionable insights.

In the current work, Shap (SHapley Additive exPlanations) [5] analysis was performed to obtain information from a machine learning hydraulic model simulation. Industry-standard EPANET [6] simulation software was used to simulate the Anytown hydraulic simulation benchmark. An Artificial Neural Network was trained using the generated synthetic data. Shap values analysis was performed on the projected findings creating insights into how prediction values were affected by each of the input variables.

The benefits of this Explainable AI [7] approach in generating insight and interpreting neural network results are discussed. How may this assist engineers in solving water distribution issues for Smart Cities?

Keywords— Machine Learning; Water Distribution Systems; Hydraulic Simulation models; Explainable AI (XAI); Shap Values; Artificial Neural Networks

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