TEchMA2023

6TH INTERNATIONAL CONFERENCE ON TECHNOLOGIES FOR THE WELLBEING AND SUSTAINABLE MANUFACTURING SOLUTIONS

AVEIRO, 25 AND 26TH OF MAY 2023

tema centre for mechanical technology and automation | dem universidade de aveiro department of mechanical engineering

LASI

FCT Fundação para a Ciência e a Tecnologia

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.

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, 2023
The Director,
António Bastos Pereira

TEchMA2023

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Intelligent Systems Associate Laboratory

CENTRO 2020 | PORTUGAL 2020 | FCT Fundação para a Ciência e a Tecnologia | UNIÃO EUROPEIA Fundo Europeu de Desenvolvimento Regional

TEchMA2023

6th International Conference on Technologies for the Wellbeing and Sustainable Manufacturing Solutions

Book of abstracts

Content

Program

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III	**2. Technologies for the Wellbeing** a. Multiscale technologies and devices for medicine, environment and energy	**Thursday, 25th of May** ROOM - 22.3.2.
IV	**1. Sustainable Manufacturing Solutions** b. Nanoengineering & Bio-inspired manufacturing	**Thursday, 25th of May** ROOM - 22.3.2.
V	**1. Sustainable Manufacturing Solutions** a. Manufacturing processes & Simulation	**Friday, 26th of May** ROOM - Auditório José Grácio
VI	**2. Technologies for the Wellbeing** b. Innovative technologies for Smart Cities	**Friday, 26th of May** ROOM - 22.3.2.
VII	**2. Technologies for the Wellbeing** a. Multiscale technologies and devices for medicine, environment and energy	**Friday, 26th of May** ROOM - 22.3.17.

SUSTAINABLE MANUFACTURING SOLUTIONS

Design and customization of an automotive door panel through hybrid additive manufacturing

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Abstract - **The field of User Experience (UX) and Human Machine Interface (HMI) is rapidly changing, and the expectations of car users for on-board experiences are becoming increasingly demanding. To meet these expectations, there is a growing need for new features such as sensors, actuators, and communication functions to be incorporated into automobiles. These demands will require innovative approaches to design and production that combine mechanical and electronic functions, ultimately leading to the development of new ideas [1]. Industries are responding to this challenge by exploring innovative controls that integrate seamlessly into surfaces, making the car more connected with passengers. As a result, the manufacture of complex shapes that were previously unachievable or impractical will become feasible and viable for implementation in the automotive industry. One promising technology that could facilitate this evolution is hybrid additive manufacturing with integrated sensors, this is, for example, the use of robocasting integrated with multijet printing. These technologies enable the creation of unique parts that can replace a part constituted by several components. The result is a more streamlined and efficient system, which can be customized to meet specific requirements. To realize the potential of this technology for the future of automotive customization, we propose an approach that combines design thinking, additive manufacturing, and sensor integration. This approach will enable the creation of highly customized parts that meet the diverse needs of car users. By incorporating sensors into the parts, we can also improve the overall functionality and safety of the vehicle. In conclusion, the use of hybrid additive manufacturing with integrated sensors presents a promising opportunity for the automotive industry to meet the demands of car users for highly customized, connected, and efficient vehicles. However, further research and development are needed to optimize this technology for widespread adoption.**

Keywords— User experience; Automotive; Lattice Structures; Automobile Customization; 3D Printing; Hybrid Manufacturing

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TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

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4D Printing: Can additives influence the morphing performance of PLA-based materials?

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***Abstract* — 4D printing emerges as a new concept of 3D printing, allowing to develop dynamic and responsive structures to external stimuli, such as light, humidity, heat, pH, or magnetic field [1,2]. The shape memory polymers, such as polylactic acid (PLA), are a promising class of materials to achieve the fourth dimension [2, 3]. Nevertheless, as the morphing effect depends on multiple factors, such as chemical composition, microstructure, and morphology of the raw materials, along with the processing methods and material layout, its control is still a challenge. In this work, the impact of additives (e.g. plasticizers, pigments) on the morphing performance of PLA-based materials was studied. Two types of PLA-based filaments were studied: a commercially available filament (with additives) and a filament extruded in the laboratory (without additives) using a Noztek pro tabletop single-screw extruder. The influence of additives on chemical, thermal, melt-flow, and morphing properties of PLA was evaluated. FTIR spectra of the commercially available PLA was identical to the neat PLA. However, as expected, it showed a lower melting temperature and lower fluidity than the pristine PLA. From the morphing effect point of view, the doped PLA required 36 s to recover its original shape, *ca.* 3 times higher than the neat PLA needed. Therefore, the additives often used to enhance the performance of PLA-based materials can delay their morphing ability and must be taken into consideration during the feedstocks selection for 4D printing applications.**

Keywords* — *Additive manufacturing, fused filament fabrication, poly(lactic acid), shape memory materials, thermal stimulus

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TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

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Experiments on Fused Filament Fabrication over freeform surfaces

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***Abstract*— Fused Filament Fabrication (FFF) in one of the most widely spread additive manufacturing (AM) technologies, partly due to the great availability of equipment. While the process allows great design freedom for the printed parts, the designs generally start from a flat surface and are printed in planar layers [1].**

Some studies have explored the feasibility of FFF print over different materials, such as fabrics and wood, proving the adhesion capability of the process [2, 3]. Also, non-planar approaches have been used to allow better adaptability to low slopes designs, improving the design freedom of the process [4].

The ability to directly modify existing objects opens countless possibilities for the consumer: such as customizing, adding functionality, repairing, and creating objects with two or more different materials. Industrial manufacturing has driven research and development into technologies such as direct etching and directed energy deposition, which can deposit layers on uneven surfaces. However, replicating these features in 3-axis FFF equipment is a difficult task, mainly due to the reliability, repeatability, and quality issues [3].

A study was carried out, to apply greater knowledge and innovation, in the FFF over irregular surfaces, later allowing the addition of material, creating new forms, as well as personalizing existing parts, through the digitalization of the substrate, CAD manipulation and generation of 3D trajectories to add new features.

The purpose of this work was to explore innovative printing strategies, such as nonplanar layering in irregular surfaces by FFF. This allowed the addition of PLA material, creating new forms, as well as personalizing existing parts. The substrate irregular surface was digitalized, and the CAD design was manipulated to ensure the generation of 3D mixed trajectories able to accurately print the CAD model in the irregular surfaces.

The development process explored the use of a Delta Wasp 4020 equipment and the adaptation of the print head. Two different solutions were developed and through thermal simulation one of them was chosen and implemented. Multiple deposition strategies were studied and developed and subsequently proceeded to printing. Finally, adhesion tests were carried out on the printed parts, where it was possible to verify a 76% increase in adhesion strength with the use of a non-planar deposition according to the free surface.

Keywords -Additive manufacturing, 3D printing, freeform surfaces

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TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

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Fabrication of thin walled structure via Wire-based Laser Metal Deposition

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***Abstract*: Wire-based Laser Metal Deposition (WLMD) is a type of Additive Manufacturing which uses laser beam to melt and feed wire feedstock on a substrate to build layer by layer a 3D object . This method is used in various industries such as aerospace [1] , construction, automotive [2] and medical devices [3]. The advantages of this method are ability to use wide range of conventional welding materials such as steel, copper, titanium and high deposition rate compared to powder-based equivalents. Also, the wire feedstock is cheaper, safer and more abundant than powder feedstock. Due to the independence of the heat source from the material feeding and the complexity of process control, WLMD has only been recently beginning to find industrial applications. In this paper, we investigate the deposition of thin-walled structures via WLMD. For our experiments, a Meltio M450 was used to deposit AISI 316L stainless steel with laser power 500 W, scanning speed 450mm/min wire feed rate 10 mm/s. The processing window was investigated and the problems concerning the deposition process were troubleshooted. The main problems observed as over-building, deposition gap, balling, dripping, etc have been occurred due to the processing parameters and machine's setting. A geometrically optimal structure was printed and tested for geometrical accuracy.**

Keywords— Wire-based Laser Metal Depisition, failure analysis, SS316, SS304 L

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

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***Abstract*—The surging field of polymer bonded carbon nanotubes (CNTs) has provided promising opportunities for transferring inherent properties of CNTs into macroscopic applications in composite materials [1], electric drive technology [2], and thermal insulator [3], etc.**

The aim of the present work was to study physical properties including mechanical, thermal and morphological properties of multiwall carbon nanotube reinforced polylactic acid composites (MWCNT/PLA) manufactured by fused filament fabrication with varying process conditions and CNT concentration. CNTs were first compounded with PLA and extruded into feedstock filaments at different CNT loadings. The properties of the home-made MWCNT/PLA filaments were first evaluated by means of morphological, thermal and mechanical investigations. Then, the effects of CNT concentration (0.5 wt.%, 0.75 wt.%, and 1.0 wt.%) as well as infill density (60 %, 80 %, and 100 %) on mechanical properties including tensile strength, elastic modulus and elongation at break of 3D printed composites were carefully analyzed by tensile testing. The deformation processes and failure mechanisms of laminated composites were analyzed in association with morphological evolution. Besides, a FEM model was developed considering the percentage of infill to predict the modulus of elasticity of FFF parts with low computation time but promising accurate results.

The results showed that the rigidity of 3D printed PLA/CNT composites were significantly reinforced without losing ductility with limited introduction of CNT. Compared to PLA specimens (100% infill density), 3D printed CNT/PLA composites presented an increase in tensile strength, elastic modulus and elongation at break up to 27 %, 53 % and 8 % in the corresponding optimal condition, respectively. In addition, it was found that lower infill density induced lower tensile properties of 3D printed specimens. Composites with infill density of 60 % presented the lowest tensile strength and elastic modulus. Finally, the simplified FEM model presented in this work allows to predict 3D printed parts using some practical assumptions, but keeping accurate results.

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

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Phase change material's 3D printing encapsulation

Development and optimization of phase change material's macroencapsulation processes and systems

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***Abstract*— During recent years, the research and studies focusing on Phase Change Materials (PCM) have been increased significantly due to their impact on the energy efficiency of multiple thermal systems [1]. However, analyzing recent and previous research studies about the use and application of PCM, a lack of solutions to incorporate these materials into real world applications is identifiable [2,3]. Most of the studies that use pure PCM incorporate them into macrocapsules constructed with manual methods, culminating in unreliable and defective systems. These methods are not ergonomic or adaptative, and also have limitations on the filling process being repetitive and troublesome, which is worsened in large-scale scenarios [4]. In addition, this makes not only the scientific data gathered unreliable, but also makes consumer market penetration low, as producing these macrocapsules is not economically viable.**

Recent advancements in the additive manufacturing industry show promise in creating possible solutions to overcome PCM encapsulation problems. There have been already developments in this field where researchers tried to make 3D printed capsules viable to hold PCM, as in Pandis et al. [5] and even 3D printing PCM directly, regarding the work of Yang et al. [6].

This work presents the development of a novel framework for the macroencapsulation of PCM with the assistance of additive manufacturing. The aim of this work is to develop both systems and processes that allow users to repeatably and efficiently produce a certain design of macroencapsulated PCM, according to the required specifications.

The development and optimization of the PCM macroencapsulation processes and systems are supported by an experimental campaign and numerical approaches. Exploratory results about the use and reliability of the PCM macroencapsulation was attended from experimental trials, in this case using an organic PCM (Chrodatherm53) in PETG capsules.

***Keywords*— PCM; 3D Printing; Macroencapsulation**

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Selecting a heterogeneous mechanical test for sheet metal characterization

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***Abstract* — Accurate simulation of sheet metal forming processes in a virtual environment requires a good understanding of the mechanical behavior of sheet metal. However, the characterization of the material behavior involves a time-consuming and costly classical testing procedure. Due to that, standard mechanical tests are being overtaken by new testing methods. These present more complex configurations and, thus, richer mechanical fields, providing a greater variety of data on material behavior [1]. Full-field measurement techniques such as Digital Image Correlation (DIC) are able to extract data from the test, taking advantage of the large quantity of information they provide. Although several test designs have already been proposed, selecting the best test to calibrate a material model remains a key challenge [2]. This study aims at proposing Key Performance Indicators (KPIs) to rank mechanical tests based on their ability to improve the material behavior characterization process. Three different mechanical tests, obtained from distinct design approaches [3,4,5], are analyzed using the proposed KPIs. Numerical information is extracted from a uniaxial load test up to rupture. The performance of each test is then evaluated and compared based on their ability to provide accurate and reliable mechanical data for characterizing sheet metal behavior. The results show that the KPIs are effective in ranking the different test designs and in identifying the most informative test. This highlights the importance of considering the design of mechanical tests when characterizing sheet metal behavior and the potential benefits of using KPIs to guide this process.**

Keywords— heterogeneous tests; KPIs; material behavior; sheet metal.

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DISCLAIMER

The results reflect only the authors' view, and the European Commission is not responsible for any use that may be made of the information it contains.

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Analysis of springback in 3rd gen steels

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***Abstract*— The increasing climate change effects bring the need to implement measures to reduce the emission of greenhouse gases. Steel producers have been developing for automotive industry different steel grades with good mechanical properties to reduce vehicle mass and fuel consumption. The 3rd generation steels have gained momentum and are being developed for this purpose. Springback is a common problem in forming operations of sheet metals. The objective of this work is to evaluate if the springback occurs in this material and to determine which are the main factors that influence the springback in this new class of steels. To this end, the material (CR980XG3TM) was tested in bending, using different tools geometries developed under the master thesis of Pedrinho [1]. Specifically, four V-shape bending tests were carried out varying punch radii and punch angle, and one U-shape bending test, with constant fixed angle and radii. V-shaped punches have a punch angle of 60º or 90º and a radius (R) of 5 or 10 mm.**

In the execution of the bending tests, two pieces of equipment were used: the Shimadzu AG-X plus to apply the load and the GOM ARAMIS 3D 5M system whose function is to measure deformation on the specimens using video cameras. To calculate the springback, two photographs captured by the Aramis were analyzed: a first photograph of the moment of maximum flexion, and a second photograph of the moment of unloading (after removal of the load exerted by the punch). With the aid of the Solidworks software, the maximum bending angle and the unloading angle were determined in both photographs. Since steel undergoes strains throughout the bending test, which were subsequently analyzed using the Aramis software, the strain occurred in the specimens was also studied to establish a relation with the geometry of the punch and the specimens' springback.

Regarding springback results, increasing the angle from 60º to 90º, but maintaining a radius of 5 mm, the springback increases; however, the opposite is observed in the situation where the radius is 10 mm. Increasing the radius from 5 mm to 10 mm, maintaining a 60º angle, increases the springback, but the opposite occurs with the 90º punch. Regarding strain analysis, it can be concluded that tools with a radius of 5 mm cause higher strain values, compared to tools with a radius of 10 mm. The specimens subjected to the V-P60R10 punch (i.e. V shape, 60º angle and radius 10) have the lowest values of strain but also suffered greater springback, compared to the other test specimens. On the other hand, the V-P60R5 (V shape, 60º angle and radius 5) and U-P (U shape) punches are responsible for a smaller springback but cause higher values of deformation in the specimens. It can be concluded that the highest strain values were caused by the 5 mm radius punches, which also registered a smaller springback, except for the V-P90R5 punch which reached the second highest springback value.

With this analysis, it can be seen that the geometry of the tool influences the amount of springback in the specimen and it is possible to relate this phenomenon to the deformation occurred in the specimen.

Keywords— springback; steel; bending

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Development of Statistical Model and Experimental validation of Mechanical behavior of fragrant screwpine fiber reinforced polyester

(Statistical model for the mechanical properties of a novel polyester composites)

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***Abstract*— Recent developments in the field of composite materials have aroused great interest in major applications. However, the world's manufacturers of next-generation composite materials are primarily concerned with sustainability, environmental awareness, and the use of green resources. Natural fibers are considered the most promising reinforcement of composites due to their biodegradability, low density, local availability, and renewable character. The pragmatism and durability of a novel polyester composite reinforced with fragrant screw-pine fibers were investigated for research purposes. The polyester composites were fabricated with different fiber fractions and fiber lengths to determine their mechanical properties. Hirsch's model was used to evaluate the experimental results of tensile property and for optimization; mathematical models were established using regression analysis. The estimated mechanical properties derived from the statistics show a good level of conformity with the experimental values.**

Keywords*— *Fragrant screwpine fiber; Polyester composite; Mechanical properties, Statistical model.

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Mechanical Assessment of Transposed Cable in Power Transformers Windings

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***Abstract*— Power transformers are crucial asset on the electrical energy networks, and they play a key role in the energy transition from fossil-based systems to renewable energy sources, since that renewable energy sources generate electricity intermittently, at varying levels depending on factors such as weather and time of day and in remote areas. To distribute this electricity efficiently and effectively, power transformers are used to step up or step down the voltage of the electricity, matching the needs of the grid and of the consumers. Power transformers support the integration of renewable energy sources into the existing grid infrastructure and ensures a stable, reliable and efficient supply of electricity under a high diversity of conditions. Power transformers 35 to 40 years or even more, [1]. However, like all electrical equipment, they can be affected by a variety of factors that can impact their reliability. Some of the key factors that can affect the reliability of power transformers include external severe environmental events, as lightning and earthquakes, transformer ageing, overvoltages and overcurrents, among others. On the power transformers, the windings, tap changing system, magnetic core, tank, and bushings are the main components. This work aims to study the mechanical behavior of the continuously transposed cable (CTCs), that composes the windings. These CTCs are subject to eletromechanical loads, including short circuits, which instigate large electromagnetic forces on the windings, [2]. This phenomenon is one of the most critical failures of the power transformer, causing permanent damages on the CTCs of the windings or even a complete failure of the equipment. This work addresses the mechanical characterization of these CTCs and the failure mode due to the buckling effects. Previous work on experimental characterization of CTCs supported this work, to create numerical models for critical load calculation of a CTC in a winding. Several analytical formulations were evaluated, [3-5], which estimate the critical load with analytical solutions of a curved beam subjected to an axial load. However, the boundary conditions considered in those models are simplified, since that the CTCs limits are not completely rigid or completely free. To overcome this limitation, simulations models are also considered on this study aiming to create a more refined model. In addition, non-linear buckling is evaluated considering a finite element model. Free buckling and forced buckling were evaluated using the impact of forces. Using the experimental results from different CTCs specimens, was possible to calibrate the finite element model, improving the simulation. These models will allow to improve the design criteria and improve the reliability of power transformers, being more tolerant to short circuits. The final calibration of these models can take advantage of calibration and model updating tools, using data from the experimental characterization and from the transformer operation.**

Keywords*— *Power transformers; windings; CTCs; non-linear buckling; computational mechanics

Fig. 1. Typical winding buckling failure, [2].

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Experimental studies of shear-thickening fluids with cork

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***Abstract*— Shear thickening fluids (STF) are a category of fluids whose viscosity significantly rises under external load. The study of these fluids has advanced greatly in recent years in terms of prospective practical applications, such as the development of impact-absorbing composites.**

Following green agendas promoted by governments and legislators, this study investigates the combination of STF and other sustainable materials. Cork is a naturally occurring cellular material with a negative carbon footprint and exceptional energy absorption capacities. With varying quantities of STF material, cork agglomerates were produced. Namely, the mixture is homogeneous, in contrast to other literary works. Subsequently, a quasi-static and dynamic experimental campaign was conducted to determine the various mechanical reactions of the composites. STF serves a purpose in the mechanical behavior of cork agglomerates by providing softer deceleration rates and dispersing more energy via disaggregation mechanisms.

Keywords*— *Shear Thickening fluids, Viscosity, Shear Rate, Impact resistance, Security Protection

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Gas tungsten arc welding of as-cast AlCoCrFeNi2.1 eutectic high entropy alloy

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***Abstract*—The AlCoCrFeNi2.1 eutectic high entropy alloy is of great interest due to its unique mechanical properties combining both high strength and plasticity. Here, gas tungsten arc welding was performed for the first time on an as-cast AlCoCrFeNi2.1 alloy. The microstructural evolution of the welded joints was assessed by combining electron microscopy with electron backscatter diffraction, synchrotron X-ray diffraction analysis and thermodynamic calculations. Microhardness mapping and tensile testing coupled with digital image correlation were used to investigate the strength distribution across the joint. The base material, heat affected zone and fusion zone are composed of an FCC + B2 BCC eutectic structure, although the relative volume fractions vary across the joint owing to the weld thermal cycle. The BCC nanoprecipitates that existed in the base material started to dissolve into the matrix in the heat affected zone and closer to the fusion zone boundary. Compared to the as-cast base material, the fusion zone evidenced grain refinement owing to the higher cooling rate experienced during solidification. This translates into an increased hardness in this region. The joints exhibit good strength/ductility balance with failure occurring in the base material. This work establishes the potential for using arc-based welding for joining eutectic high entropy alloys [1].**

Keywords— AlCoCrFeNi$_{2.1}$; Gas tungsten arc welding; Synchrotron X-ray diffraction; Thermodynamic calculations; Mechanical testing; Digital image correlation

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Laser Marking on Aluminum Alloys

Process parameters and surface treatment effect on marking quality

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***Abstract* — Laser marking is a process that has gained significant importance and is widely used in industry [1]. Due to the growing need for product identification and traceability, this technology is applied in marking component serial numbers, barcodes, QR codes, etc. This technology offers numerous advantages over other marking methods, such as high accuracy, speed, versatility, quality, and the ability to mark a wide range of materials, including aluminum alloys [2]. However, the type of laser and the appropriate marking parameters, such as the marking speed, power and frequency, are essential to achieve high-quality long-lasting markings.**

In this study, a fiber laser with a power of 30 W and a wavelength of 1064 nm was used to make markings on AW6082 aluminum bars with a natural layer of aluminum oxide. In order to study the influence of speed, frequency and power on the marking quality, sets of parameters were defined. Six different laser scanning speeds were tested: 200, 450, 650, 850, 1000 and 2000 mm/s. For each speed, the power varied from 10 % to 100 % and the frequency from 10 kHz to 80 kHz, both with increments of 10.

The results showed that the markings varied in color and quality. Dark markings were obtained with a combination of lower frequency parameters, high power and lower speeds. As the speed increased, the markings became lighter. For the parameter set of speed 450 mm/s, power 100 % and frequency 30 kHz, good quality dark markings were obtained. On the other hand, good quality white markings were obtained at 1000 mm/s, 100 % power and 10 kHz frequency. The marking quality was also influenced by the marking strategy, with the presence or absence of contours and the filling method used. Since the aluminum bars did not have any surface treatment, over time, some markings and unmarked areas showed high amounts of oxidation. It was also found that oxidation affected the marking's legibility, with oxidation more prevalent in the deeper markings, that is, dark markings, compared to the light markings. Thus, a comparison was made between the markings on the aluminum bars without surface treatment and on a piece with an anodized surface. It was found that the markings made on the anodized part showed a high marking quality, as well as a significant decrease in oxidation over time. The surface treatment also affected the color of the markings, giving them a more uniform color.

Laser marking is an increasingly important and widely used technique in various industrial sectors. In the case of marking on AW6082 aluminum surfaces, the results obtained indicate that surface treatment by anodizing can significantly improve marking quality and oxidation resistance. These results are important for optimizing laser marking processes, which in turn are useful for companies that use the technique under study in their production.

Keywords — Laser Marking; Surface Treatment; Fibre laser; Oxidation; Marking Quality; Aluminum

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Surface quality in the helical milling of the Ti-6Al-7Nb alloy - a case study

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Abstract — The use of titanium alloys in the manufacture of medical devices, namely orthopaedic implants, seeks to take advantage of their mechanical properties such as high biocompatibility, low Young's Modulus, high resistance to fatigue and corrosion, making them preferred for this type of applications over cobalt-chromium alloys and stainless steel [1].

The Ti-6Al-4V alloy is currently the most used in the manufacture of orthopaedic implants such as screws, prostheses among others. However, problems related to toxicity and the fact that it still has a very high Young's modulus compared to bone are reasons why it is necessary to develop new alloys that allow its use without increased risk for the patient. Among others, the Ti-6Al-7Nb alloy, also of the α+β type, is one of the alloys proposed as an alternative to the Ti-6Al-4V alloy, that seeks to solve the biocompatibility issues mentioned above [2].

This work aims, through a hole-making operation using the helical milling process [3], to compare, the surface quality of holes made in Ti-6Al-4V and Ti-6Al-7Nb alloys, based on the roughness parameters Ra, Rt and RzD, the surface quality of holes made in Ti-6Al-4V and Ti-6Al-7Nb alloys. For this purpose, were carried out helical milling tests on test samples of the referred alloys with constant cutting speed (Vc) and three variations of feed per tooth (fz) and depth of cut (ap).

From the obtained results, it was possible to observe that, in terms of the roughness of the drilled holes, the Ti-6Al-7Nb alloy presented a behaviour very similar to that of the Ti-6Al-4V alloy, having in some cases lower roughness values. Therefore, it is possible to conclude that, from a manufacturing point of view, the Ti-6Al-7Nb alloy can appear as a valid alternative to produce medical devices. Concerning helical milling, its suitability for drilling holes in difficult-to-machine materials [4] such as titanium alloys was confirmed. Also, in this process, the best roughness results were obtained with lower fz and ap, the latter being the most influential parameter on roughness.

Keywords— titanium alloys, Ti-6Al-7Nb, Ti-6Al-4V, helical milling.

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On the identifiability of sheet metal constitutive parameters using the Arcan test

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***Abstract* — In modern industry, modelling and simulation are crucial phases of product development. Sheet metal forming processes typically involve large deformations and complex phenomena. As a result, modelling the behaviour of the materials during forming requires complex constitutive models and high accuracy in their calibration to produce a realistic simulation of the forming processes. During the last decades, a huge effort was made by the scientific community to develop precise constitutive model formulations in elastoplasticity, including complex yield functions [1], and isotropic and kinematic hardening models [2]. However, due to the increased flexibility of the mathematical formulation and the consequent increase in the number of constitutive parameters that must be calibrated, the identification of the parameters of such models involves a complex calibration procedure. Classically, the calibration was done using standard homogeneous tests, where each test represents a single stress/strain state. As a result, an extensive experimental campaign is usually required to fully characterise the material behaviour. Nowadays, with the use of heterogeneous test configurations and full-field measurements, it is possible to measure a combination of multiple stress/strain states. This rich kinematic data can be used in inverse identification techniques, such as the virtual fields method [3], to identify multiple parameters from a single test with reduced cost and time [4]. Moreover, the richness of the measured kinematic data is highly dependent on the test configuration used, and while the Arcan test has been used in sheet metal plasticity by some authors, it is rarely used in heterogeneous test design for plastic constitutive model calibration. Nonetheless, the Arcan test is an interesting test configuration since it allows the loading direction to be varied in a standard uniaxial tensile testing machine.**

This study presents a numerical evaluation of the Arcan mechanical test to identify plasticity constitutive parameters of a dual-phase steel (DP600). The numerical model used considers the anisotropy and hardening of the material. Several Arcan test configurations are simulated and further evaluated regarding their mechanical state heterogeneity using a set of indicators. This approach presents a methodology for selecting the most suitable configuration.

Keywords— Sheet metal forming; Inverse calibration; Anisotropic plasticity; Arcan test; Heterogeneous test evaluation.

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Process-informed constitutive model selection

Statistical analysis to rank types of constitutive models

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***Abstract*— Nowadays, the aeronautics and automobile industries are in high demand for the quality of their products and the efficiency of processes. Thus, virtualization and digitalization are a trend for the design, development and manufacturing of products which lead to low costs, no delays and less waste. High-quality metal products often require realistic numerical simulations prior to manufacturing, and the choice of the constitutive model significantly affects the accuracy of the predicted material behavior. While numerous material constitutive models exist [1-3] to describe various mechanical phenomena, selecting the appropriate model is a laborious task requiring specialized expertise. A lack of knowledge in model selection can result in errors in numerical predictions, leading to costly delays in the manufacturing process. To address this issue, an automated material model selection tool is necessary. This study aims to compare the impact of different constitutive models on the simulation of a forming process and develop a systematic strategy for model selection. The approach involves analyzing a hole expansion test using Abaqus and conducting a statistical analysis of variance (ANOVA). This strategy was already implemented in [4-6] as a Design of Experiments (DoE) approach to determine the influence of geometric factors on the springback of sheet metal parts, but the authors believe that it can be extended to a more general analysis that supports the constitutive model selection for numerical simulations. In this work, it was possible to establish a ranking of the most important model types that can support model calibration and improve prediction accuracy.**

Keywords*— *Constitutive model selection; Model's ranking; Numerical simulation; Mechanical process; Analysis of variance (ANOVA).

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DISCLAMER

The results reflect only the authors' view, and the European Commission is not responsible for any use that may be made of the information it contains.

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Development of a female finite element model of the cervical spine

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***Abstract*— The cervical spine a common site of injury in the vertebral column, with severe injuries resulting in permanent disabilities. However, most are minor with a low threat to life. One of the most common neck injuries is whiplash, and the plethora of clinical symptoms and sequelae have been classified as whiplash-associated disorders (WAD). The risk of sustaining WAD has been shown to be significantly influenced by gender. Females are at higher risk of developing symptoms [1]. Additionally, finite element human body models have proven to be fundamental tools for better understanding injury mechanics. As such, the aim of this work is to create a new finite element of the female cervical spine that will more accurately represent the group most affected by such injuries.**

The initial geometry of the created model was obtained from the CT scans of a 49-year-old female subject and was generated using a hybrid methodology of combining medical images and parametric studies. Four different components were modelled, the vertebrae, the intervertebral discs, the facet joints, and the ligaments. Initially, all components were assumed to be isotropic materials with linear elastic properties to simplify the first simulations. Additionally, all ligaments were set to work only in tension. Furthermore, seeing that the vertebrae are relatively stiff structures, these can be modelled analytically as rigid components, making the analysis more efficient. As such, additional simulations were performed considering all bony components as rigid. It is possible to analyze and validate sections of the spine before simulating the entire model. As such, the model was divided into functional spinal units (FSU). The FSUs were subjected to six moments of pure moments of 1Nm working in flexion, extension, axial rotation, and lateral bending. Throughout the applications of the loads, the range of motion (ROM) was monitored.

The accuracy of the developed model was validated by comparing output predictions with previously published experimental data [2,3]. As of the time of writing, only one FSU, the C6-C7 segment, has been completely validated, with the first simulations showing satisfactory outcomes. The only test that shows results outside of the experimental range is lateral bending. However, this stiffness has been found in previously validated FE models [4,5].

Keywords*— *Cervical spine; Functional spinal unit; Finite element method; Range of motion; Biomechanics; CT scan

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Fixation of calcaneal fractures with a new type of osteosynthesis plate

(Preliminary study)

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Abstract — Calcaneal fractures usually occur due to a traumatic event, such as a fall or a car accident, and 60-75 % of fractures in this bone are intra-articular, with fragment displacement [1]. Thus, most of these injuries are approached surgically, and the prognosis depends on the stability of the internal fixation of the bone fragments [2]. For this purpose, osteosynthesis plates are currently removed and discarded after the bone has healed. In this context, plates with filigree patterns are an alternative that allows the use of the device after its extraction, converting it into a personal object for the patient. This study aims to verify, through a finite element study, if this type of plate can be used to stabilize calcaneus fractures.

A CAD model was generated using Solidworks. A Sanders type II fracture was virtually simulated by a space of 0.5 mm, creating an anterior and a posterior fragment. The bone fixation is achieved using an osteosynthesis plate (placed laterally using five cortical screws) and two percutaneous screws inserted posteriorly. Two 1.5 mm thick and 60 mm long customized plates (with and without the filigree patterns, differing only in the interior design) were simulated using ABAQUS software. Cortical and percutaneous screws are represented by cylinders measuring 2.1/5.5 mm in diameter and 20/45 mm in length, respectively. Bone structures were simulated as elastic linear isotropic materials with Young's modulus (E) of 10 GPa and 1.45 GPa and Poisson coefficients (v) of 0.3 and 0.2 for cortical and trabecular bone, respectively. The surgical material properties simulated were those of stainless steel 316L (E=193GPa, v=0.27). The load applied to the posterior face of the calcaneus is intended to simulate the action of the Achilles tendon, with a force of 138 N being applied in the direction of its axis of action [2]. Simultaneously, two joint zones (talar and cuboid) were fixed in space. The contact surfaces were connected to prevent movements between them, except for the contact established between the plate and the bone and between screws and plate, with a coefficient of friction of 0.2.

Introducing patterns in the osteosynthesis plate creates stress concentration points, the maximum stress being higher (155 MPa) than that recorded in the non-pattern plate (139 MPa). Despite this, the stress is lower than the elastic limit of the material simulated (given that the tensile strength of the stainless steel considered is 600 MPa), and, therefore, none of the plates predicts material failure for the considered loads. Furthermore, fixation of the calcaneus, although less stable, is successful with the plate with filigree patterns, not allowing substantial displacement of the fragments [3]. In the future, it may be necessary to evaluate other factors (such as plate geometry and material) and different contexts to introduce filigree patterns in osteosynthesis plates without affecting their performance.

Keywords — biomechanics; biomaterials; filigree; osteosynthesis plates; calcaneus.

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Comparison of Finite Element Methods in Fusion Welding Processes—A Review

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Abstract— Currently, welding processes have become one of the most used methods for joining materials in all kinds of industries, thanks to properties such as high speed and high tensile strength. However, despite these advantages, this type of connection method has some drawbacks, for example, residual stress and structural distortion, mainly due to the process thermal cycles. Structural distortion is one of the major concerns of industrial joining practice. In order to decrease distortion, the variation of welding sequence, direction, and clamping conditions, have been applied through several years, by trial-and-error tests. However, numerical simulation enables virtual examination of the welding, mainly due to the progress on the numerical methods, which stimulated the research on welding simulation models. These models can cover a wide spectrum of physical and thermal processes occurring during, and after welding. The aim of this paper is to provide wider information about types of finite element method (FEM) in fusion welding processes and to demonstrate the accuracy of FEM models results compared to experimental.

Keywords— welding simulation; finite element method; inherent strain theory; welding distortion

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Rheocasting Simulation

(Automobile component manufactured by Rheocasting)

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Abstract—A emergent foundry process is Rheocasting, in which the metal to be cast, in the form of a semi-solid mixture, is pressure-formed into a mould. This process was born from the need to produce components with higher structural integrity. Rheocasting needs that, prior to injection, the material be maintained at a constant temperature between solidus and liquidus while being subject to a physical process – usually mechanical stirring – intended to generate a globular morphology for the solidified metal grains, thus replacing the dendritic morphology which tends to occur under normal solidification conditions. As a result, the injected material exhibits a thixotropic behaviour, which is conducive to a reduced presence of defects due to air entrapment and shrinkage. Computer Aided Engineering (CAE) techniques have, in the latest years, been a part of the production process of parts by the foundry. CAE contributes to minimising design errors, maximising productivity, reducing waste and maximising the final product's structural integrity. Because every process has intrinsic manufacturing defects, having previous knowledge of what to expect during production is very important. During the design phase, it is then possible to preventively alter the part's geometry or the processing conditions to avoid defects and improve the final quality levels of the production. The typical manner to use CAE techniques, which may be of various natures, is iterative, repeated until a satisfactory result is achieved before proceeding to production. As expected, this is critical when demand is high and requires high production levels and short lead time. This work presents a simulation study of the Rheocasting manufacturing process of an aluminium automobile component. This Simulation allows for locating the predict critical structural integrity points. The Simulation limitations are presented and discussed. It is concluded that Simulation is essential for the design phase, and communication between the experimentalist and the simulation programmer throughout the process is paramount to ensure the production of solid castings.

Keywords— Rheocasting; Quickcast; Simulation; automobile components.

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TOPIC

1) Sustainable Manufacturing Solutions
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Cold crackings on dissimilar welding of differential case

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***Abstract*— Cracking have been observed in welded differential case, a dissimilar laser welding between cast iron from the differential and low carbon steel from the ring crown with the addition of a filler material [1]. These cracks are delayed cracks, i.e., so-called cold cracks, developing at the Heat Affected Zone on the ring crown side. It is known that the conditions for cold crack initiation and propagation are governed by the triptych of microstructure, stress state and hydrogen availability. Therefore, the identification of the hydrogen sources and its possible impacts on cold cracking after the welding of the differential case was chosen as the subject of this work. Several sources of information directed the study towards carbonitriding as a potential hydrogen source [2,3]. Hydrogen flow measurements corroborated this hypothesis. Also, a second series of measurements at different stages after carbonitriding were done to try to elucidate the impact of the time between some of the operations, of the manufacturing of the ring crowns, on the cold cracking of welded cases. These results show that tempering it's crucial for degassing the hydrogen and that even at room temperature this degasification it's not negligeable.**

Keywords*— *Dissimilar welding; LASER; steel; cast-iron; crack; hydrogen.

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Double-depth texturization and bioactive coatings via laser technology for zirconia dental implants

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***Abstract*— In the natural dental system, the alveolar bone, periodontal ligament and healthy gums ensure and support chewing without occlusal load. However, this system suffers daily exposure to several physical and chemical factors that cause deterioration and can lead to total tooth loss. Dental implantology has significantly improved the quality of life of 5 million patients annually. Recently this industry has been investing in zirconia-based implants [1]. Several studies have been conducted to strengthen zirconia's mechanical and bioactive characteristics, making it an increasingly functional material to promote rapid osseointegration [2, 3]. In this topic, surface modifications to bioactive, antibacterial and angiogenic coatings have gained significant relevance [4, 5]. This work used laser surface technologies to texture three patterns on zirconia and laser sintering mesoporous bioactive glass S53P4 coatings to improve cellular activity. The coatings were sintered using conventional and a laser sintering treatment to evaluate laser sintering as a potential fast sintering process. Analyses using SEM, profilometry, EDS and XRD were performed to select the optimised laser parameters and obtain the best quality patterns and bioactive coatings. Mineralisation tests were performed to indicate the best laser pattern and sintering conditions samples as the candidate for a new mesoporous bioactive coating for osteointegration improvement of zirconia dental implants.**

Keywords*— *Zirconia Dental implants; Laser surface functionalisation; in vitro tests.

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Characterisation of an additively manufactured 3D cross-based fractal structural for impact energy absorption with different volume fraction

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***Abstract*—Designers are proposing to use high performance materials [1] or cellular and bio-inspired structures in components with high strength-to-weight ratios, high heat transfer capacity, and energy absorption. An example of these designs is fractal geometries. However, the mathematical transformations of fractal objects result in highly complex 3D geometries that are unfeasible using conventional manufacturing processes. Additive manufacturing (AM) [2] processes can fill the technology gap. The present work investigates the energy absorption performances of a 3D cross-based fractal structure (3D-CFS). The geometry is inspired by the mathematical 3D Greek cross geometry [3] and designed for the production using laser beam powder bed fusion process for polymers (PBF-LB/P), in particular, Polyamide (PA12) [4]. The effects of the process and the volume fraction on the mechanical properties of the structure are evaluated using quasi-static and high-speed compression tests. From these results, the energy absorption performances are estimated. Owing to the strain-rate sensitivity of PA12 produced by PBF-LB/P, the energy absorption efficiency of the 3D-CFS structure decreases by increasing the strain rate. The results show that the 3D-CFS structure is a good candidate for shock absorption applications such as personal protective equipment (PPE) applications.**

Keywords - PPE; PBF-LB/P; Fractal; PA12; shock absorption.

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Coral Reef Restoration

(A new nature centered design approach)

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***Abstract*— Coral reefs are the most diverse ecosystem of marine life, home to tens of thousands of different species. They are of great importance, providing food, coastal protection and absorbing 26% of the CO2 emitted into the atmosphere [1]. The effects of climate change result of global warming, ocean acidification, intensive fishing, and pollution, are drastically changing coral reefs, leading to their degradation. It is estimated that by 2050, 90% of the world's population of coral reefs will be damaged [2]. After acknowledging the need to restore and increase marine ecosystems, there is the potential to implement artificial reefs. However, most common artificial approaches, such as sunken vehicles and prefabricated cement reefs, do not allow an appropriate coral adhesion [3]. These artificial reefs don't have the 3D complexity of coral habitats. With the help of additive manufacturing techniques and design thinking methods, designers can find new ways to create artificial reefs with the required level of characteristics that corals need to attach to reefs to be alive and healthy [4]. This research focuses on the development of artificial reefs through generative design and using additive manufacturing to provide better coral adhesion. A "Nature Centered Design" approach will be followed, in which corals are the center of the design project [5]. With this approach, data on the surfaces that corals prefer will be obtained. Tile samples with different geometries and roughness using the Paste Based Extrusion technique will be tested. First the material is tested to prove that it is inert, then coral samples are attached to the tiles, through asexual reproduction, where the attachment and the growth of the corals will be analyzed and monitored weekly. With these tests, it is thus possible to obtain a biological response from corals that allows to understand their preferences. It is expected the definition of an optimized surface and a coral-compatible material, capable to mimic the geometries of natural reefs, such as protrusions, openings, and indentations. The Nature Centered Design approach will allow creating a working model that can be customized depending on the implementation area or the intended coral species. With additive manufacturing technology, it is possible to customize the product quickly, allowing for in-situ printing, reducing the CO_2 that normally is emitted during the transportation. The presented methodology offers a solution model that can be used in any coral reef restoration project, or any project related to environmental restoration. This research will validate the design approach as a methodology that aids environmental preservation, taking advantage of additive manufacturing and generative design as customizable and innovative processes in coral restoration.**

Keywords*— *Generative Design, Corals, Additive Manufacturing, Artificial Reefs, Nature Centered Design, Ocean Sustainability

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Development of Shear Thickening Fluids for Impacts Mitigation

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Abstract—Shear thickening fluids (STF) viscosity increases as the shear rate increases [1]. They go from a liquid-like state at lower shear rates to a solid-like state at higher shear rates, characterized by a quick increase in their viscosity [2]. Therefore, STF is a very interesting and promising material for several application fields where a different mechanical behaviour is demanded based on loading rates, e.g., shock absorbers, body armour and vibration insulators. For instance, Tan et al. [3] investigated shear-thickening fabric composites (STFC) subjected to stab, drop-weight, Split-Hopkinson pressure bar (SHPB), and ballistic impact. The results showed that STF inevitably flow away from the surface of STFCs without any protection and that shear-thickening gel has better stability and is easier to encapsulate. In another study, Kevlar® fabric was impregnated with STF and subjected to ballistic tests. It was possible to conclude there is a significant improvement in ballistic penetration resistance due to the addition of STF. The samples performed equivalently to neat fabric targets of equal areal density while offering significantly less thickness and more material flexibility. Additionally, there is a proportional relationship between the energy absorption by the STF-fabric composite and the STF volume [4]. At this point, it is known that STF synthesis is possible through the mix of fumed silica nanoparticles and poly(ethylene) glycol, even though there is no pattern concerning the synthesis conditions reported in the literature. The STF maximum viscosity, critical shear rate, and agglomerate size of particles depend closely on the concentration of fumed silica, stirring time and speed [1]. This work aims to develop an STF for the mitigation of low-energy impacts. Its synthesis results from an iterative process, analysis of the rheological behaviour, and exploratory impact tests based on the impregnation of other materials.

Keywords— shear thickening fluid; impact; energy absorption.

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Luminescent QR codes of PLA/LnMOF hybrid composites

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***Abstract*— Traceability of original products is an ever-growing demand for producers and end users to verify the authenticity of produced goods. Nowadays, anti-counterfeit strategies are becoming critical to face the market of counterfeit products. Following this newfound need, we propose an anti-counterfeiting method based on a quick-response (QR) code, using luminescent lanthanide metal-organic framework (LnMOF) composites. With its exceptional optical properties it has the potential to revolutionize this application field. The embedded code will only react to a certain stimulation, hence it can only be unlocked using the sequence that is programmed to react to. For that purpose, the successful incorporation of LnMOFs, with europium (EuMOF) and terbium (TbMOF), on a biodegradable polymer matrix of polylactic acid (PLA) was achieved. The obtained composites were prepared via a two-step process including solvent casting followed by thermal mixing, to achieve a homogeneous mixture with optimized concentrations of each filler. This step was followed by filament extrusion and finally 3D printing of the codes. The samples' chemical, structural and morphological properties were assessed using different techniques, including Fourier Transform Infrared Spectroscopy (FTIR); X-ray diffraction (XRD); and Scanning Electron Microscopy (SEM). Additionally, the optical characterization was assessed by room temperature photoluminescence (RT-PL) and photoluminescence excitation (PLE). The results revealed no relevant structural modifications of the polymer and an excellent response to selective excitation, with well-defined intraionic lines for TbMOF @ 542 nm ($^5D_4 \rightarrow {}^7F_5$) and for EuMOF @ 615 nm ($^5D_0 \rightarrow {}^7F_2$). PLA/Eu,TbMOF composites were also prepared to create an additional level of encryption by tunning the emitted color with the appropriate excitation stimuli. Therefore, these new luminescent composite materials can be used as traceable optical tags for a wide variety of polymeric products, capable to respond to specific excitation wavelengths whose decoding demands the assessment of more than one factor, with near-impossible replication. Additionally, this technology has a high potential for scalability since the applied processing techniques to produce optically active QR codes are commonly employed in the polymer industry.**

Keywords*— *Luminescence; MOFs; Recyclable; Sustainable, Scalable, 3D printing; Anti-counterfeiting.

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TOPIC

1) Sustainable Manufacturing Solutions
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Confining materials at the nanoscale for cancer therapy

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***Abstract*— Cancer is one of the leading diseases in the world. According to the World Health Organization In 2020, more than 19 million people were diagnosed with cancer, resulting in 10 million deaths. The number of people with cancer is expected to rise, with an estimated 30.2 million new cases by 2040. (https://gco.iarc.fr/) The development of new nanomedicines allowed for the emerging of innovative ways for the early diagnosis and treatment of cancer. [1] Indeed, in the past few years, a number of treatments based on nanomaterials have been cleared for clinical use. These include polymeric, liposomal, and inorganic nanoparticle formulations, with different levels of synthetic complexity.[2]**

Carbon nanocapsules (CNCs) have been shown to be very promising multifunctional nanoplatforms for detecting and treating cancer. The major advantage of CNCs is their ability to hermetically seal large amounts of active agents and deliver them specifically to tumor cells. In this way, it will be possible to avoid the possibility of degradation of the active compounds while also decreasing their potential risks of biotoxicity. The first reported CNCs were made from carbon nanotubes, and were successfully used for in vitro[3] and in vivo[4] bioimaging by hermetically sealing high loads of contrast agents with high levels of toxicity (Pb and Ba) that are hard to handle (gases). Recently, their use has been expanded to the treatment field by making "hot" CNCs by sealing radioactive compounds (153Sm). These CNCs were able to provide high-resolution bioimaging and radiotherapy against lung cancer metastases after being injected intravenously.[5] Carbon nanodots (CDs) also showed that they could encapsulate atomically dispersed gold, proving in this way a new effective avenue for cancer nanotheranostic.[6] The results showed that imaging-guided CDs strongly reduce tumor growth (in carcinoma models) by inducing mitochondrial oxidative stress, without causing severe side effects. Recently, CNCs produced via carbon nanohorns showed the potential to accumulate enriched compounds for the implementation of a new therapeutic approach in the field of neutron cancer therapy[7].

Keywords*— *Carbon nanocapsules ; cancer; bioimaging and therapy

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Carbon dots for mitigation of metals contamination

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***Abstract* — Water is a valuable resource for ecosystems and human existence, but it has been threatened significantly by pollution. Heavy metals generated by anthropogenic activities are considered a persistent group of contaminants that have been severely contributing to water pollution and its consequent deleterious effects on ecosystems, including bioaccumulation on aquatic organisms and biomagnification along the trophic chain. Several approaches have been developed over the years to mitigate pollution from metals. Recently, carbon dots (CDs), which are 0-D carbon-based nanomaterials with diameters below 10 nm, have attracted great attention due to their optical and electrical properties, and high biocompatibility [1]. These properties confer CDs with high relevance in several applications, including as agents for environmental remediation [2]. Indeed, CDs have functional groups that allow them establishing strong interactions with metal ions, potentially reducing their biotoxicity in aquatic ecosystems. In literature, there is some study describing the efficiency of CDs in the removal of metals. For instance, Hg+2, Cd+2, Cr+3, or Pb+2 ions were independently removed with high efficiency by CDs synthesized from Red Malus floribunda fruits [3].**

In our work, we used embryos of zebrafish (Danio rerio), a well-known model organism that is often used in toxicology to study how contaminants affect aquatic environments. We looked at how well CDs could absorb metal ions and reduce their toxicity. S-/N-doped CDs were synthetized solvothermally using citric acid, urea, and indocyanine green [4]. To provide high reaction yields (44%) and homogeneous samples (5.8±0.6 nm in diameter), the crude product was directly purified by size exclusion chromatography in water. The tested metals were cadmium, nickel, and silver. Embryos were exposed, according to the OECD guideline 236 [5] to binary combinations of CDs (0, 5 or 50 mg/L) and several concentrations of each metal in a full factorial design. For the 3 metals tested, a reduction in toxicity was observed when metals were combined with CDs. For instance, when CD = 5 mg/L were added to metal solutions, the LC50 value (concentration lethal for 50 % of the organisms) increased 2.7 times for cadmium; 1.3 times for nickel, and 2.3 times for silver. Other parameters analyzed, such as embryo hatching delay and swimming activity disturbances, also followed the same trend. These preliminary results indicate a strong potential for CDs to monitor and reduce metal biotoxicity in aquatic ecosystems. In future work, other metals should be tested and scaled-up experiments conducted.

Keywords: Carbon dots, Metal ions, Zebrafish, toxicity

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Carbon Dots@Aminoporphyrin Hybrids for Enhanced Photodynamic Therapy

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***Abstract* — Extensive research has been focused on Carbon Dots (CDs), a new class of fluorescent carbon nanoparticles with sizes smaller than 10 nm. They are typically composed of carbon, nitrogen, and oxygen atoms arranged in a graphitic structure. CDs have unique optical properties, including strong photoluminescence, high fluorescence quantum yield, and tunable emission wavelengths [1]. These properties make them promising nanomaterials for a variety of applications, such as sensing, optoelectronics, energy conversion, and biomedical. In photodynamic therapy (PDT), a photosensitizer is administered to the patient, which selectively accumulates in the tumor tissue. Upon excitation with light of a specific wavelength, the photosensitizer generates reactive oxygen species (ROS) that can cause substantial damage to the tumor cells, leading to their death [2]. Aminoporphyrins are a class of porphyrin-based photosensitizers that have been widely studied due to the unique features that make them attractive candidates for PDT. Aminoporphyrins have strong absorption bands in the visible and near-infrared regions, which enables deeper tissue penetration and have high singlet oxygen quantum yields, which is a key factor for efficient ROS generation [3]. This work mainly focuses on the functionalization of CDs with aminoporphyrins to produce nanohybrid materials with enhanced photophysical and phototherapeutic properties. CDs were synthesized by two different methods, top-down and bottom-up approaches, followed by its carboxylation to improve drug loading and consequently enhance phototherapeutic activity. The final step consisted of the conjugation of CDs-COOH with aminoporphyrins by the EDAC method in order to successfully obtain the hybrid materials [4]. Future work will consist of evaluating the performance of these new nanohybrid materials as theranostic agents for PDT and bioimaging of cancer cells.**

Keywords* — *Aminoporphyrin, Cancer, Carbon Dots, Bioimaging, Photodynamic Therapy, Photosensitizer, Reactive Oxygen Species.

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Uniform Mo2C nanoparticles derived from Mo132 cluster as efficient electrocatalysts for hydrogen evolution

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***Abstract*— Molybdenum carbide (Mo2C) is a promising electrocatalyst for hydrogen evolution reaction (HER). They can be obtained by high temperature calcination of molybdenum precursors, including molybdenum salts (e.g. MoCl5), molybdate (Na2MoO4·2H2O) or small polymolybdate clusters ((NH4)6Mo7O24·4H2O or PM12) with carbon precursor. However, inevitable nucleation of such small Mo precursors leads to severe sintering, which limit the catalytic activity of the resulting Mo2C electrocatalyst. Herein, a sub-nanometer keplerate Mo132 cluster is chosen as molybdenum precursor to synthesis Mo2C-nitronge-doped graphene hybrids (Mo132/NrGO) as novel electrocatalysts. Uniform anchoring of Mo132 clusters on graphene oxide (GO) sheets was achieved by using a positively charged poly(ethyleneimine) (PEI) as binder and carbon/nitrogen precursors. After thermal annealing at 800 oC, a hybrid electrocatalyst composed of nitrogen-doped graphene substrate decorated with uniform and size narrowly distributed Mo2C nanoclusters (2.5 ± 0.5 nm) can be obtained. The effectiveness of this strategy is confirmed by unevenly distributed and much larger Mo2C nanoparticles obtained from smaller Mo7 polymolybdates under TEM observation, as well as the more than doubled active electrochemical surface area (9.56 mF cm-2 vs. 4.27 mF cm-2) of this novel Mo132/NrGO electrocatalyst based on the assessment of their double-layer capacitancse (Cdl). As a result, the Mo132/NrGO electrocatalyst displayed superior HER performance including a marginal overpotential of 62 mV to reach a current density of 10 mA cm-2, a small Tafel slope of 57 mV dec-1, as well as a large exchange current density (j0) of 1.19 mA cm-2 in acidic 0.5 M H2SO4 electrolytes. The calculated turnover frequency (TOF) at 100 mV is 0.70 s-1, superior than most of recently reported Mo2C electrocatalysts. Therefore, using large Mo132 clusters as molybdenum precursors open a new avenue for design and synthesis of size controlled high performance Mo2C catalysts.**

Keywords*— graphene; hydrogen evolution reaction; molybdenum carbide; polyoxomolybdate

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Study of Thin-Walled AISI316L LMD Manufactured Parts

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***Abstract*— The development of new flexible laser-based systems for Laser Metal Deposition (LMD) is due to the current demand of the industry for solutions to produce complex structures, with curved interior cavities, thin barriers and honeycombs that aren't reached through conventional technologies as well as carrying out repair operations for parts with high added value** [1][2]**. LMD industrial use demands research about the influence of the parameters in the built parts density, accuracy and mechanical properties. Especially for the thin-walled parts, knowledge about the correlations between processing parameters and the final result is indispensable. This study explores the relationship between process parameters: laser power, feedrate and layer thickness, and the quality of AISI316L stainless steel thin-walled parts produced by LMD. A six-axis robot allowed the spatial movement of the deposition head relative to the substrate with high accuracy. In the LMD process, the adjustment of the kinematics is of utmost importance to manufacturing thin walls with complex geometries, as occurs in thin-walled parts.**[3]**. Controlled energy input provided by continuous wave Ytterbium fibre laser allows less material flow rate and the production of thin layers in test samples. Three processing parameters were selected to investigate the effects on AISI316L parts' characteristics using a Box-Behnken experimental design. The parameters were evaluated in the spectrum of 600 W to 800 W laser power, 6 mm/s to 14 mm/s feed rate and 0.2 mm to 0.4 mm layer height. All remaining parameters were fixed using argon to provide an inert atmosphere, 8.8 g/min powder feeding rate and 1.5 mm laser spot diameter. The method was used to test the manufacture of thin-walled cylindrical specimens 10 mm in height and 75 mm in diameter. Fabricated samples were evaluated regarding the dimensional and geometrical characteristics** [4]–[6]**. The material density and hardness were also investigated. It was observed that higher energy input density during laser additive manufacturing results in lower geometric precision, at 610W power, 8.3 mm/s feedrate and 0.39 mm layer thickness. Feedrate and layer thickness have the highest impact on both the wall thickness and vertical accuracy. While it was possible to optimize the parameters to improve the geometrical accuracy, the maximum part deviation is still significant and surface quality is kept rough due to residual stress, over deposition or deposition miss accuracy and loose powder clouding effect. Given this inability to produce parts with acceptable surface quality, the process finds great applicability when complemented with additional finishing technologies.**

Keywords— AM; LMD; tool steel; thin-walled

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Recovering of recycled expanded polystyrene via extrusion

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***Abstract*— Expanded polystyrene (EPS) is a polymer consisting of 98% air and 2% polystyrene (PS) [1]. EPS parts are made up of PS beads that contain a blowing agent, typically pentane, entrapped into their interior, which allows them to expand to form a cellular structure similar to a honeycomb [2]. The unfoamed expandable beads permit efficient storage and transportation, as well as their density control in separate steps (pre-expansion and molding) [2]. The low density and excellent mechanical and thermal properties of EPS make it widely used in insulation and packaging applications [1]. However, many applications of EPS have a short service life, emphasizing the need for efficient recycling methods [3]. Furthermore, the European targets Green Deal aims to achieve carbon neutrality, requiring the circularity of raw materials and strategies to minimize the use of virgin feedstocks [4]. The most used EPS recycling method involves shredding and extrusion into recycled PS granules for use in other applications. Yet, this process, which is known as downcycling, destroys the cellular structure of EPS, while releasing the blowing agent, compromising their further reprocessability [3]. This work aims to recover the value of recycled (shredded) EPS through the extrusion process by adding a blowing agent to produce granules similar to those produced in the more conventional process (suspension polymerization) [2]. This approach has the potential to create a closed EPS recycling loop. Herein, a mechanical prototype that allow to introduce an expanding agent during the recycled EPS extrusion was developed.**

Keywords*— *Expanded Polystyrene (EPS); Mechanical Recycling; Extrusion; Thermo-mechanical Degradation; Expandable Beads; Blowing agent

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Cork Composites for Sustainable and Eco-friendly Applications in Aerospace Sector

Educational Perspective for Cork Composites in Aerospace Applications

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***Abstract*— In recent applications, composites have been developed by including natural products such as cork. Cork is a suberous casing of the species Quercus Suber tree, also known as cork oak. Mediterranean coasts of Europe, especially Portugal and Spain, include the major territories of cork oak and 90% of cork products are produced from there in the world. Cork forests protect the environment from desertification while providing suitable habitat for several animal and plant species. This lightweight material exhibits elastic and thermal/vibration isolation properties while retaining imperishable behavior. In current applications, cork is used as an insulation material in engineering. Although cork products have been already utilized in different applications, the usage rate of cork is very low in major industries such as aerospace. However, the European Union (EU) policies and reports from different organizations all around the world call attention to environmental problems and thus, eco-friendly and sustainable materials gain importance for future applications. Leading organizations have investigated advanced composites from natural products. For this reason, cork is a candidate natural material for engineering applications due to its excellent properties as well as imperishable behavior.**

Aerospace is a leading sector for the usage of sustainable and eco-friendly natural materials such as cork. The main reason for the selection of aerospace industry as the implementation sector is that this industry is familiar to cork composites as using them in aircraft, helicopters and space shuttles. Moreover, aerospace industry is the leading sector for the development of natural composites since huge amounts of investments are made by the companies and governments. Scientific developments mostly emerge in aerospace industry then spread to the other sectors.

This study aims to develop educational materials for gaining environmental awareness of eco-friendly composites as well as understanding the importance of cork in sustainability. Within this scope, partners in a EU funded project, namely ECOCORK, have developed an educational scheme, and the partnership has been concentrated on individuals at the college level. After developing a curriculum, the partners have produced a textbook about cork in aerospace applications. In addition, lesson presentations and videos have been prepared for supporting students in learning about cork composites. For self-assessment of the students, a set of quizzes has been produced. Moreover, staff skills have been enhanced in a particular and promising field with the interactions between pacemaker partners. An industrial partner has contributed to the preparation of training programs on sustainability and carbon footprint of cork products since it is a leading cork producer globally.

Keywords— sustainability; cork; aerospace applications.

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Reuse of residues from the SLS process using the use of alternative production technologies

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***Abstract*— One of the most used materials in Selective Laser Sintering (SLS) is Polyamide 12 (PA12). In the SLS process, 80 to 90% of the powder present in the construction chamber is not being sintered[1]. However, during the heating process, this polymer suffers from thermal degradation, which restrains the number of times that the used material but not sintered can be reused again. The laser sintering market value is growing, exhibiting a CAGR (Compound Annual Growth Rate) of 22.13% [2] and with this growth, more PA12 waste goes to the landfill.**

This study aims to evaluate an alternative production technology to reuse the PA12 after its use in SLS process (the PA12 which cannot be reprocessed again). The evaluation included the use of PA12 in the Fused Deposition Modeling (FDM) process and Thermoplastic Injection Moulding (TIM).

In order to achieve this objective a state-of-the-art analysis was made on polymers, PA12, the processes used in its recycling, its mechanical and thermal properties and the FDM and TIM processes. With this review it was possible to reach conclusions such as the reuse of the powder the melting temperature increases and the fluidity index decreases [3], a correlation between the fluidity index and the superficial quality of the pieces [4] and while achieving good superficial quality may not be feasible, it is anticipated that the mechanical properties will not experience a significant decline [5].

The experimental process will start soon with a differential scanning calorimetry (DSC) and a flow index test (MFI) to obtain the thermal and rheological properties of the PA12 waste supplied by CENTIMFE. Once all the properties are known, the processing conditions for FDM and TIM can be determined.

With the specimens formed, it is possible to start to perform mechanical tests, such as traction tests, with which it will be possible to measure properties such as maximum stress, yield stress and tensile strength.

Keywords— Polyamide 12; Powder reuse; Selective laser sintering, Powder thermal decomposition .

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Lightweight biocomposites for a new generation of circular economy-enabled visual communication boards

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***Abstract*— In visual communication boards (VCB), the substrate role is to provide a stable and durable structure for the writing surface. Typical VCB substrates are constituted by rigid wood fiber-based boards and/or plastics that can be laminated to a metallic writing surface or coated to enable a smooth writing/erasing experience. Notwithstanding, laminated structures rely on covalently bonded multimaterial structures, which compromises the VCB recycling and ecological footprint, and therefore to develop a new generation of sustainable and circular economy-enabled VCB is paramount.**

In this work, the feasibility of compounding thermoplastic starch (TPS) and acid polylactic (PLA), two biobased polymers, with calcium carbonate (CaCO3), as a filler, to develop lightweight VCB was studied. The influence of PLA and CaCO3 on mechanical properties (i.e., tensile) and water contact angle of TPS was investigated. Moreover, the suitability of using silica-methyl modified alkoxysilanes (SMMA) to enhance the writing/erasing surface of TPS/PLA/CaCO3-based materials was evaluated. Furthermore, aiming to develop a VCB prototype, a mold for thermocompression was developed and a life cycle analysis of the most promising biocomposite was assessed.

Keywords—product development; thermocompression; life-cycle analysis; composite.

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TOPIC

1) Sustainable Manufacturing Solutions
   c. Manufacturing for Circular Economy

Non-destructive reprocessed PLA degradation evaluation and control in FFF filament extrusion

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Abstract — **There are, nowadays, multiple techniques available to sort and evaluate the quality of reprocessed plastics with increasing accuracy, especially when paired with suitable prediction algorithms. Some of those techniques can, additionally, be used in-process and non-destructively, as is the case with in-line spectroscopy and rheology [1]. The first objective of this work was to evaluate the potential of rheology, and near-infrared (NIR) and Fourier-transform infrared (FTIR) spectroscopy to generate data that allowed a degradation level classification in reprocessed poly(lactic acid) (PLA) for small-scale closed-loop additive manufacturing.**

Material degradation can be triggered, during PLA reprocessing, especially in the melt-processing stages. At the molecular level, degradation causes chain scission of the polymer molecules, leading to a decrease in molecular weight. This gradually renders the material unsuitable for further processing or to produce new parts with no downgrade, as altered melt behavior and mechanical properties result from polymer degradation phenomena [2]. Through the addition of a chain extender additive in the reprocessed plastic it is possible to mitigate this [3]. This leads to the second objective of this work, to characterize the capability of 1,3-bis(4,5-dihydro-2-oxazolyl)benzene (PBO), a chain extender understudied in PLA, to recover the initial PLA's properties.

To achieve this, PLA was subjected to one or two consecutive cycles of extrusion, printing, through fused filament fabrication (FFF), and grinding, after which, formulations were developed with varying PBO concentrations. The formulations were granulated, extruded, and printed. Double capillary rheology, NIR, FTIR, differential scanning calorimetry (DSC), tensile tests and print quality assessment were performed.

By collecting data on material degradation and its mitigation, as described previously, the basis for a system integrating in-process, non-destructive, degradation assessment and mitigation in the context of small-scale closed-loop additive manufacturing, is created. This, in turn, will lead to an extension of the number of reprocessing cycles PLA can go through, minimizing quality loss.

Keywords— closed-loop manufacturing; Additive Manufacturing; polymer degradation; quality assessment; chain extender.

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Developing additive symbiotic networks through the adoption of blokchain technology

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***Abstract*— Additive manufacturing has been widely recognized for having unique features which can support the implementation of circular economy strategies** [1]**. Namely, the development of additive symbiotic networks** [2]**. In these industrial symbiosis networks, waste materials are used as material inputs for additive manufacturing processes. Considering the exchange of resources between different stakeholders that form a symbiotic network, there is a need to find tools that support the implementation of transactions within the network** [3]**. Within the industrial symbiosis network context, blockchain technology has been acknowledge as a tool to boost the development of additive symbiotic networks** [2], [4]**. Despite of its potential benefits, adopting this innovative technology is expected to have impacts within the supply chain structure of an additive symbiotic network** [5]**. The literature on the development of additive symbiotic networks is still scarce, as well as the on the use of blockchain technology in such settings** [2], [4]**. This exploratory research intends to promote the development of additive symbiotic networks through the adoption of blockchain technology, to contribute to the existing literature research gap and seeking to revitalize global partnerships to achieve global sustainability. Two case studies regarding two distinct additive symbiotic networks were conducted to achieve two main objectives: to identify the requirements to use blockchain technology in an additive symbiotic network and to identify the main implications of adopting this technology in the supply chain structure of the an additive symbiotic network. In both networks, plastic waste from different industries is incorporated in additive manufacturing processes to manufacture new products. In case study A, plastic waste from a manufacturing company is used to produce home furniture pieces. In case study B, plastic waste streams from post-recycled consumer waste are used to produce recycled filament for 3D printers. Results from this research confirm that blockchain technology can be used as an enabler of additive symbiotic networks and identifies the requirements for using this technology in such symbiotic setting. Moreover, this research also identifies the main implications of adopting such disruptive technology in the supply chain's structure of an additive symbiotic network. Namely, blockchain technology is expected to have implications within the power re-distribution of the network's stakeholders. To support the adoption of blockchain technology in additive symbiotic networks context, future research work related to the development of a blockchain-based architecture to support the implementation of an additive symbiotic network is suggested.**

Keywords*— *additive symbiotic networks; blockchain technology; circular economy; supply chain structure.

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Bismuth-induced synthesis of Au–X (X = Pt, Pd) nanoalloys for electrocatalytic reactions

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***Abstract*— Due to the synergistic effect and structural advantages, bimetallic nanostructures are widely regarded as excellent catalysts for hydrogen evolution reactions and methanol oxidation reactions [1]. Although the traditional galvanic displacement reaction can effectively prepare bimetallic nano-alloys with significant potential differences [2-3], it is still a difficult challenge to prepare precious metal nano-alloys with similar standard potentials. This work reports a general wet chemistry method, for the first time introduces the intermediate element Bi, which has a lower potential and is easy to alloy, and produces Au-X (X=Pt and Pd) bimetallic nanoalloy using a galvanic displacement reaction with the Au-Bi modified ITO electrode as the templates. The morphology and composition of the samples were characterized by means of scanning electrochemical microscope (SEM), ultraviolet-visible absorption spectroscopy, XRD and high-resolution transmission electron microscope (HRTEM). The catalytic properties of the obtained nanoalloys were studied by cyclic voltammetry (CV) and linear scanning voltammetry (LSV). The results showed that in alkaline media, Au-BiX (X=Pt andPd) bimetallic nanoalloys show good catalytic activity in hydrogen evolution reaction and methanol catalytic oxidation. In addition, the simple and versatile galvanic displacement reaction (GRR) for introducing Bi intermediates can also be used to manufacture other multimetal nanoalloys with similar electrode potentials and compositions.**

Keywords*— *Nanogold; galvanic displacement method; multi-element alloy; hydrogen evolution reaction.

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TECHNOLOGIES FOR THE WELLBEING

Artificial Neural Network Modelling of Solar Thermal Hybrid Façade

Artificial Neural Network Modelling Approach and Results

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Abstract— Climate change and sustainable development are some of the leading 21st-century challenges, probably one of the most significant challenges we have 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). Renewable energy costs are becoming increasingly lower since the technology is well known and devices are 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, cooling (using a geothermal network) and ventilation.

Further to its residential utilisation, 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 façade model of the façade was created using an Artificial Neural Network (ANN).

The use of artificial neural networks in various applications related to renewable energies, energy management in buildings and thermal systems analysis has been increasing significantly over the years [1-3]. This technique is characterised by its requirement to use data collected previously from a working prototype or a simulated system. Collected data should describe the system performance and can be used afterwards to train the network, replicating the façade's working behaviour. After a considerable period of data gathering [4], the collected data was used to generate a set of neural networks, one ANN for each operating mode (air only, water only and hybrid ways) and meteorological typology (clear sky/cloudy sky), totalling six networks. The most common ANN layouts, which presented better results, are based on one hidden layer network (5 out of 6); tansig and logsig activation functions are evenly used amongst the selected models. For the training algorithm, the best results were obtained from the Levenberg-Marquardt algorithm (5 times out of 6). The analysis of the percentual error of measured accumulated energy vs predicted accumulated energy for the various façade operating modes points to a deviation between a maximum of 6.6% for the hybrid mode with cloudy sky and a minimum deviation value of 0.2% for the water-only mode with clear sky.

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

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A numerical model for domestic hot water tanks integrated with heat pump water heaters

Development and experimental validation

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***Abstract*— Promoted by European policies on using renewable energy, heat pump water heaters (HPWHs) are crucial for achieving a sustainable and low-carbon future. Many factors, including the design, working media, and temperature of the heat source and heat sink, highly influence these systems. The main components and the complete system's development, design, and optimization are often carried out using numerical simulations rather than experimental testing, significantly reducing the required resources, costs, and time [1]. In previous editions of this conference, the authors presented some studies on numerical simulation and validation of the main HPWH components, particularly devoted to transcritical CO_2 heat pumps. As HPHWs contain a vapor compression system coupled to a domestic hot water (DHW) tank, developing and validating an integrated model involving both systems is of major relevance.**

It is possible to find some available open-source DHW tank models, including the EnergyPlus water tank model and the TRNSYS (stratified, non-stratified, and thermocline) tank models. Nevertheless, these models are based on 1-D simplifying assumptions to make the simulations computationally efficient, which do not capture all system complexity [1,2] and lead to inaccurate simulation results. On the other hand, a computational fluid dynamics (CFD) model produces more detailed and accurate representations of fluid flow and heat transfer but requires a great deal of time to evaluate the energy efficiency of the whole system [3].

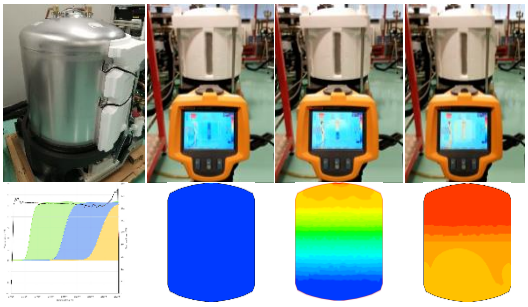

Figure 1 – Graphical abstract.

The development of a detailed numerical model for DHW tanks integrated with HPWH, balancing counterparties between simplified 1-D and CFD models, is proposed, presented, and discussed. The proposed model is validated using experimental data from a campaign for the performance rating of a transcritical CO_2 HPWH according to EN16147 standard [4].

***Keywords*— transient model; heat pump; hot water tank.**

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The future of adsorption heating and cooling technologies

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***Abstract*— Heat pumps are among the most environmentally friendly technologies to be integrated with intermittent renewable energy sources [1]. Since heat pumps can reduce greenhouse gas emissions, their importance has recently grown. Nonetheless, the heat pumps market share is still meagre, accounting for just 5% of the buildings' heating sector in 2019. Under the Sustainable Development Scenario, heat pumps representation in the market must triple by 2030, which will require several technological improvements, installation and purchase costs reduction, increased energy performance, removal of market barriers, and enforce the use of alternative refrigerants [2]. Policymakers from several countries are setting incentives towards embracing and disseminating heat pumps throughout society, recognising and promoting the contribution to a low-carbon future in the transition to a more sustainable energy society [3].**

The conventional heat pumps in the market are electricity-driven vapour compression heat pumps (VCHP). Although many efforts have been made to reduce their global warming potential (GWP), VCHP still mostly rely on refrigerants (HFCs and HCFCs) with significant GWP. Due to their low environmental impact, adsorption heat pumps (AHP) have attracted the interest of researchers and gathered the heating and cooling market's attention over the last few years. Their importance has been rising mainly due to two key characteristics. Firstly, they can work with natural refrigerants, such as water and ammonia, with zero GWP, which are environmentally friendly, abundant in nature, and easy to deal with [3]. Secondly, AHP are driven by thermal energy, which can result from waste heat and renewable energies like solar, biomass and geothermal energy. However, AHP still have a lower coefficient of performance (COP) when compared to conventional VCHP. Although the lower COP is often considered a significant disadvantage, it must be remembered and reinforced that AHP are directly driven by heat, which can be freely obtained. The development of an adsorption system for cooling applications seems very promising and more prone to compete with vapour compression systems, both economically and environmentally. Engineering creative solutions to capture heat that is freely available and use it to drive an adsorption cooling system to provide cooling for industrial processes, residential and industrial buildings, data centres, agriculture, fish and animal farms, among other applications, is the key to achieve a competitive adsorption cooling system. Therefore, the near future of adsorption heating and cooling technologies will rely on the creativity of engineers and researchers to find ways to harvest and use this free heat to drive adsorption heating and cooling technologies. Furthermore, it is possible to use adsorption heating and cooling systems in a hybrid way for simultaneous seawater desalination and heating or cooling providing. The perspectives for further investigation on adsorption heating and cooling technologies are high, which may lead to new solutions and products that are energetically sustainable and more economically competitive.

Keywords*— *adsorption heat pumps; adsorption heating; adsorption cooling; sustainable energy.

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Improving thermal comfort and water savings in domestic gas water heaters

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***Abstract*— Awareness that natural resources are limited is a crucial step towards ensuring the sustainability of future generations. By 2030, 1.8 billion people are estimated to live in areas with an absolute lack of water and water scarcity will affect about 70% of the world's population [1]. In addition, the burning of fossil fuels is another problem with a worldwide impact, with only 22% of the energy consumed in the EU coming from renewable sources [2] when water heating represents a fraction of 15% of energy consumption in the domestic environment [3].**

Tankless gas water heaters (TGWH) are widely used to produce hot water for domestic use, the most efficient conventional method to heat water using natural gas [4]. Despite its advantages over other water heating systems, one of the relevant drawbacks is undesirable water temperature oscillations. When subjected to variations in hot water demand, sudden temperature changes with overshoots or undershoots cause waste of water and energy, unwanted emissions, and a negative impact on the user's comfort [5]. This project intends to build a solution that helps to overcome these problems, reducing the amount of water and energy wasted. At the same time, the user waits for comfortable hot water to arrive at the tap. The user can attach this module to the water heater equipment he already owns, not forcing him to purchase an entirely new appliance to increase the energy sustainability of his home.

In this work, a simulation study and the construction of a prototype are presented. The modelling of the dynamic behaviour of the tankless gas water heater, the dynamic analysis of the different assembly schemes of the system, the definition of an adequate layout, the control scheme of the closed-loop system, the CAD modelling of the mechanical design and the selection of design elements, such as the dimensions of the pipes, solenoid valves, reservoir, water mixing block, temperature sensors, LCD panel and microcontroller and prototype details are discussed.

Keywords*— *domestic hot water; tankless gas water heaters; thermal; comfort; mechanical project; temperature; control

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METHIS Digital Services Platform

Primary Health Care Digital Transformation

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***Abstract*— In 2019, chronic diseases accounted for 7 of the top 10 causes of death globally, accounting for 74% of deaths globally. Chronic disease management is pathology-driven and often poorly coordinated within various specialities, making care fragmented and inefficient. Recently, a transition has been seen in managing chronic disease, increasingly benefiting from Digital Health Services (DHS). Empirical evidence shows that DHS are valuable tools to improve care for people with multimorbidity (two or more chronic conditions) - both from the patient's and the health professional's points of view [1],[2]. However, it can also be observed that new digital tools, when implemented incorrectly, also increase the health professional's workload, are inappropriate for patients, and do not bring added value to the disease management process [3]. The METHIS Project was born out of the need to create a digital platform aligned with the conceptual goals of clinical pathways management of multimorbidity in Primary Health Care. As such, it aims to provide evidence on better and more innovative ways to change the organisation of healthcare for Multimorbidity patients by implementing a value-based Digital Health Service. Based on Design Science Research Methodology, this project focused on developing a digital platform that assists GPs in the long-term care of patients with multimorbidity by improving communication and patient engagement. Its core components promote care coordination, optimisation of disease priorities and patient self-management, always focusing on adding value to care processes. As METHIS is considered a Digital Health Service, it is also based on a business model (including sensor integration and professional and data integration). It has a multidisciplinary research team (General Medicine, Nursing, Pharmacy, Public Health, Statistics and Engineering). METHIS has several publications, and a proof of concept was conducted in three Family Health Units (FHU) in Lisbon and Setubal [4]-[6]. This year, it will feature a pilot study in two more FHUs. The COVID-19 Pandemic led to an increased demand for Health Services, with PHC playing a significant role in reducing travel to Health Facilities. Since Digital Health Services are the future and given the high-impact disadvantages, it becomes essential to explore DHS with the help of value-based digital platforms to provide care to patients with chronic diseases in PHC in Portugal.**

Keywords*— *Digital Health Services; Digital Platform; Health Digitalization; Design Science.

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Automated rotational electromagnetic generator with self-adaptive structure by coil switching

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***Abstract*— As of late, there has been a marked increase in the interest surrounding the development of high-performance energy harvesters, particularly for both small-scale and large-scale applications. Energy generators can be used on a large scale to generate electrical power for the home grid as well as used on a small scale to power a wide range of devices such as smart electronics, extracorporeal and intracorporeal medical devices, wireless sensor systems, portable electronics, etc. Energy harvesting is used to collect energy from intermittent and irregular external sources such as human movement or oscillatory movements caused by nature (such as the oscillation of ocean waves or wind) [1,2]. This intermittent and irregular characteristic of the sources causes high production and maintenance costs for conventional generators compared to the necessary costs of energy harvesting generators [2]. Recently, some promising linear self-adaptive energy harvesting generators have been proposed, but these new technologies require mobile components for self-adaptation, or the consumption of the self-adaptive system will depend on the number of coils [1,2].**

This work focused on the development of an innovative self-adaptive mechanism capable of dynamically switching off, on, or reversing the polarity of a group of generator coils, depending on the angular displacement of the magnets. This mechanism can be divided into two other mechanisms: Coil Switching and Coil Polarity Switching. Coil Switching is the system responsible for switching the set of coils on and off when the axis of the coils is centered with the axis of the magnets. While Coil Polarity Switching changes the electrical connection between the coils and the external load so that certain positions of the magnets prevent the voltages from canceling each other out and thus maximize power. These self-adaptive mechanisms are independent of the number of coils in the system. To test and validate this self-adaptive mechanism, a rotational electromagnetic energy harvesting generator was developed with a small and simple architecture attached to an eccentric mass. This generator has the particularity that the number of coils is double the number of magnets.

The experimental results highlight that the generator without the self-adaptive system has an average power density of 97.1 µW/cm3 at a frequency of 5Hz, and that with the implementation of the self-adaptive system a power density of 143.6 µW/cm3 is expected. This self-adaptive system can be introduced in other electromagnetic rotational energy harvesting systems, thus increasing the performance of these generators with low implementation costs and low mechanical complexity.

Keywords*— *Self-powering; Electromagnetic generator; Adaptive generator

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An unobtrusive multimodal stress detection model & Recommender System

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***Abstract*— Studies estimate that about 50% of all lost workdays are related to occupational stress (1). In recent years, several solutions for mental health management, including biofeedback applications, have emerged as a way to enhance employee mental health (2,3). Solutions to mitigate risk factors related to the working settings present an enormous potential and a clear contribution. However, most of the work that has been developed is limited to laboratory environments and does not suit real-life needs. Our study proposes an unobtrusive multimodal approach for detecting work-related stress combining videoplethysmography and self-reported measures for stablishing the ground truth in real-life settings.**

The study involved 28 volunteers over a two-month period. Various physiological signals were collected through a videopletismography solution, while users were performing daily working, for approximately eight hours a day. In parallel, self-reported measures were collected via a pop-up application (developed by the research team) that periodically retrieved the user's perceived stress (amongst other variables) in order to label the physiological data. In order to develop the stress detection model, we pre-processed the data and performed Heart Rate Variability (HRV) feature extraction. Then, we experimented with several machine learning models, utilizing both individual and combined physiological signals to explore all available alternatives. After rigorous evaluation, the best-trained model achieved an accuracy of over 80% and an F1 Score of over 85%.

With the stress detection model in place, we are developing a structured intervention model to help reduce stress. This intervention model integrates two interconnected dimensions through digital coaching, which prioritizes personalized recommendations based on user preferences. Our top priority is to ensure user engagement, and we believe that adherence to and adoption of recommended interventions are more likely when users receive recommendations that align with their preferences. Thus, we prioritize personalized recommendations that are tailored to each individual's unique model. After detecting immediate stress peaks and providing real-time feedback on stress levels, our alarm system goes a step further by offering customized recommendations for brief stress relief.

The digital coach (intervention model) offers various recommendations and active lifestyle changes such as exercise, task management, weight management, better sleep habits, structured pauses, and other critical interventions. These critical interventions are also based on user preferences, allowing our system to prevent future stress-related incidents and, most importantly, mitigate long-term stress.

This project and its methodology demonstrate that truly unobtrusive stress detection is possible and can be performed within the scope of ethical demands. In future work, we will evaluate the responses and beneficial outcomes of implementing a recommender system.

Keywords— Occupational Stress; Machine Learning.

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RehabVerse

A Virtual Reality Game for Post-stroke Rehabilitation

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***Abstract*—Stroke is a leading cause of disability worldwide, impacting an estimated 15 million people each year. One of the most common effects of stroke is impaired motor skills, which can greatly diminish a patient's quality of life. Rehabilitation is a crucial part of the recovery process, but it can also be an expensive procedure. In recent years, virtual reality (VR) technology has shown great promise in aiding stroke recovery by providing patients with an immersive, engaging, and affordable platform for rehabilitation exercises. However, most systems are designed for aiding with the final stages of recovery. To solve this issue, a system - RehabVerse - was designed to help lower the burden on therapists, allowing them to attend to multiple patients at once. The setup created uses the Oculus Quest 2 to envelop the patient in an immersive and engaging environment, a Kuka robot that moves the patient's arms in a controlled and safe manner, and two screens that provide different views of the game - one screen displays the game's interface, which allows therapists to monitor and customize the rehabilitation routine, while the other screen shows the patient's point of view. The game allows therapists to set a customized routine that automates the process of rehabilitation. An amusement park scenario was created for the game as it is a familiar and relatable environment that can help middle-aged and older patients feel more comfortable and engaged in the rehabilitation process. The VR game features two mini-games that encourage patients to practice their upper-limb extension and flexion. In the first mini-game, patients crank a punching machine that punches a piñata, while the second mini-game involves filling up a balloon until it pops. Additionally, the VR game records data that can later be analyzed by therapists. This information can be used to evaluate the patient's progress and tailor the rehabilitation program to their specific needs [1-5].**

Keywords— Virtual Reality; Rehabilitation; Stroke; Upper-Limb.

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A multimaterial multifunctional patch to repair the spinal cord contusion injury

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***Abstract*—Due to its severe and extensive damage, spinal cord injury (SCI) results in significant motor, sensory, and autonomic dysfunction. Since traditional treatments for this condition have shown to be inefficient for functional recovery, current research is interested in cell-based therapies paired with three-dimensional platforms. With this in mind, our patch considers the synergy between the exceptional biological properties of a methacrylated decellularized adipose derived extracellular matrix (adECM-MA) hydrogel and graphene-like multisheets (GLMS), given their unique properties, including high surface area, biocompatibility, and ability to be functionalized with various biomolecules. Additionally, in order to support the stability of the ultrasoft adECM-MA hydrogel, a melt-electrowriting polycaprolactone (MEW-PCL) grid was included.**

To allow photocrosslinking, the decellularized extracellular matrix was modified by methacrylation, with a protocol that could maintain a steady pH throughout the whole procedure [1]. Given this successful methacrylation, adECM-MA hydrogels were made via photo-polymerization with a variety of adECM-MA concentrations (0.25%, 0.5%, and 1% w/v). The elastic modulus of these hydrogels could be tuned over a wide range of Young's moduli, as shown by the compressive tests, which revealed Young Modulus of 5.57 ± 2.95 kPa, 7.58 ± 2.20 kPa and 16.12 ± 4.11 kPa for 0,25%, 0.5% and 1% adECM-MA, respectively. Furthermore, given the lowest overall stiffness 0, 5, 10 and 15% (w/w) of GLMS were added to the 0,25% hydrogel, the most suitable for the neural tissue, to enhance the neuronal phenotype.

The MEW-PCL grid was printed utilizing optimized melt-electrowriting in a branched microfibrous structure to mimic the neural network. Neural stem cells (NSCs) ability to survive and differentiate into neurons was further assessed. The results showed that the soft but yet controllable architecture developed using the MEW-PCL grid and 0.25% adECM-MA was able to support the viability of the encapsulated NSCs. The MEW-PCL grid also demonstrated to enhance neuronal differentiation, with lengthy neuronal processes. As for the GLMS addition in the adECM-MA hydrogel, concentrations of 5% and 10% revealed to further promote neuritogenesis whereas 15% hindered both neuritogenesis and differentiation, showing that NSCs presented an GLMS-dose dependent response regarding neuronal differentiation.

Keywords— tissue engineering; spinal cord injury; extracellular matrix; graphene-based materials, hydrogel.

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Production of Tumour-on-a-chip parts using 3D printing

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***Abstract*— Tumour-on-a-chip (TOC) devices are a revolutionary technology that allows for the in vitro modelling of tumour development and therapy response. These devices are miniaturized platforms that mimic the biological and mechanical features of tumours, enabling for controlled monitoring and testing. TOC device development frequently involves complex geometry and requires tight control over the microenvironment, which can be difficult to obtain using typical production processes [1].**

3D printing has emerged as a potential alternative to traditional manufacturing processes, as it can build complicated geometries with great accuracy and precision, it may be utilized to develop devices that can mimic the tumour's microarchitectures. There are various advantages to the use of 3D printing for the fabrication of TOC devices, for example, provides quick and cheap prototyping, which can greatly speed up the creation of new assays, and its reproducible parts is crucial for producing dependable and repeatable outcomes [2].

In this work, the mould for the shell of the TOC was designed with microfluidic channels with a section of 100 x 200 µm and a cylindrical culture chamber with 1.5 mm diameter and 500µm of height. In a first approach, this design was printed by SLA using an Anycubic Photon and UV sensitive resin. The same design was later printed by inkjet in a Stratasys Objet 30 using VeroClear. A PMMA sheet was prepared to close the mould and inject the PDMS. A 10:1 ratio of PMDS and curing agent was used to fill the mould which was cured at 80º C for 1h. In the first prepared mould, it was observed that the photoinitiator of the resin inhibit the PDMS curing. A post printing processing step, where the printed part was under UV exposure for 20 min and at 80ºC for 1 h, was added in order to remove the PDMS cure inhibitors. The second prepared mold showed a good performance in terms of PDMS curing, without needing further treatments. In both cases, after demoulding the shell, the resulting cured PDMS exhibited well-defined microfluidic structures. Our results showed that the adoption of 3D printing for the fabrication of microfluidic devices offers an affordable and fast way of prototyping and improving its designs and architectures.

Keywords*— *tumour-on-a-chip, microfluidics, cancer models, biofabrication, 3D printing.

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An anisotropic magneto-responsive fibre-based hydrogel for spinal cord guided regeneration

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***Abstract*— The orientation of spinal cord nerve fibers is critical for brain-spinal cord electrical transmission. Patient's sensory and motor capacities are severely impaired due to the injury-induced loss of neuronal network structure and the restricted regenerative capacity of the central nervous system. Biomaterials, microfabrication and cells are being employed in tissue engineering and regenerative medicine strategies aiming to restore spinal cord physiology [1]. The purpose of this research is to determine if biomaterials with anisotropic properties that mimic the native tissue's structural complexity of human spinal cord can guide neurons longitudinally and form functional neuronal networks.**

Magneto-responsive fibers were fabricated by mixing iron oxide superparamagnetic nanoparticles (SPIONS) with a polycaprolactone-gelatin solution. Using an electrospinning system developed by our group [2], highly aligned fibrous membranes, with 80% of the fibers aligned within 15° of the anisotropy axes, were manufactured. Membranes composed of randomly oriented fibers were used as control. 2D *in vitro* cell culture studies revealed that the addition of SPIONS to the polymer fibers does not impact neural stem cells (NSCs) viability. Moreover, the NSCs cultured on anisotropic substrates adhered and spread unidirectionally, producing longitudinal interconnections, while cells cultured on disordered substrates showed a was star-shaped morphology and their connections were multidirectional. Differentiation experiments revealed that the fiber alignment promoted the formation of a linearly ordered neuronal network and inhibited the differentiation into astrocytes.

For posterior embedding into hydrogels, aligned fibrous membranes were microcut into pieces of 200x500 µm. They were posteriorly embedded in a collagen-based pre-gel solution and aligned using a magnetic device consisting of two Helmholtz coils generating a 20 mT magnetic field. When the longitudinal alignment of the fibers was achieved, the pre-gel was photocrosslinked fixing the placement of the fibers.

We produced simple magneto-responsive fiber micromembranes that may be oriented *in situ* toward defined locations with the intention of using them in minimally invasive injectable hydrogels. Future studies will include NSCs differentiation experiments in 3D anisotropic hydrogels. The implantation of this fibrous structure is meant to help neurons reconnect between the two damaged stumps of the lesioned spinal cord, thereby mending the neural network.

***Keywords*— Alignment; Anisotropic; Neural cells; Tissue regeneration; Scaffolds; Spinal cord injury**

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MnCo2O4 electrocatalyst for water-splitting devices

Oxygen evolution reaction in alkaline environment of nanocatalyst grown on 3D nickel foam

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***Abstract* — Hydrogen (H_2), being non-toxic and clean, is considered one of the great sources of energy storage, with water electrolysis being the main method to produce green H_2. In this regard, water is a clean and fossil fuel-free source, which has the benefit of avoiding carbon dioxide release when compared to the steam reforming of methane industrial process, as long as the electricity required comes from a renewable source [1].**

Currently, there are two main challenges that prevent the industrialization of the water electrolysis process: i) the high amount of energy that is consumed and ii) the choice of the material used as the electrocatalyst. The latter should minimize (as much as possible) these energy losses, thus, being able to offer reduced electrode overpotentials [2].

The main electrode reactions that have been extensively studied in water splitting cells are: HER (hydrogen evolution reaction), ORR (oxygen reduction reaction), and OER (oxygen evolution reaction). In particular, the OER is a slow anodic semi-reaction that occurs in multi-steps and generates liquid water and oxygen gas as products,

$$4OH^-(aq) \rightleftharpoons 2H_2O(l) + O_2(g) + 4e^- \quad (1)$$

Hence, the development of effective and low-cost electrocatalysts for OER is an effective and promising strategy to improve the sluggish kinetics of the OER process. In this respect, cobaltite systems with a spinel structure (MCo_2O_4) have attracted a lot of attention as catalyst materials due to the high oxidative power of cobalt oxide, accumulating excellent electrochemical properties for OER [3].

There are several synthesis routes used to obtain these inverse spinels. For example, conventional electrodes are physically connected to the current collector through polymeric binders, limiting the electrochemical stability at high current densities. Conversely, catalysts grown directly on the surface of the support do not use polymeric binders to maintain the active mass on the support, which extends the useful life of the catalyst and increases its catalytic capacity.

In the current work, we propose the use of flaxseed (*Linum usitatissimum*) as a polymerizing agent in the proteic sol-gel method, coupling this route to hydrothermal synthesis as a way to obtain $MnCo_2O_4$ directly onto the nickel foam. Comparison is made with a conventional electrode that was prepared by an ink composed of MnCo2O4 nanoparticles, ethyl alcohol and a polymeric binder, which is used to increase the binding strength between the particles and the current collector.

We observed that the electrocatalyst grown on Ni foam combines the structural and catalytic advantages of the three-dimensional network of Ni foam and manganese cobaltite, delivering a current densities of 25 mA/cm^2 and 100 mA/cm^2 at overpotentials of 296 mV and 360 mV, respectively, which are significantly better than that obtained by the conventional deposition route (25 mA/cm^2 at 353 mV). Such an electrocatalyst also exhibits superior electrochemical stability for efficient water oxidation activities at 10 mA/cm^2 for 15 h.

Therefore, the sol-gel synthesis coupled to hydrothermal proved to be an excellent way to prepare electrodes for water electrolysis, as the connection between the Ni foam and the electrocatalyst allows a larger contact surface and, consequently, faster electrochemical reactions, providing lower overpotentials.

Keywords — Water splitting; Oxygen evolution reaction; Green synthesis; Sol-gel; Hydrothermal; $MnCo_2O_4$

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Sustainable electrochemical syngas production

Development of novel electrolytes for proton ceramic membrane reactors

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Abstract — **Worldwide energy consumption has grown exponentially since 2000 due to economic development and its current dependence on the use of fossil fuels has become a major cause of climate change, causing an increase in environmental pollution. According to this situation, Europe Union leaders issued an agreement to stimulate the urgent need for energy transition aiming to make Europe a neutral continent in terms of greenhouse gas emissions by 2050, ensuring the supply of clean, safe, and affordable energy [1,2].**

On the other side, the increase in the level of organic waste production through modern societies has attracted the exploitation of biogas in order to contribute to the reduction of global greenhouse gas (GHG) emissions. According to the International Energy Agency (IEA), biogas plays a very important role, as these gases can be used in the transformation of the global energy system. In this regard, biogas can also be converted into H_2-rich gas using the reforming process to generate useful fuel or feedstock for chemical production [3].

The current study proposes an electrochemical configuration aiming to form green syngas (a mixture of CO and H_2) from a biogas precursor, by direct electrochemical pumping across a proton-conducting ceramic-oxide membrane. Differing from traditional biogas to green hydrogen or biomethane routes, this process does not consider the CO_2 content of biogas as a hindrance. Instead, the current pathway permits the conversion and utilization of the entire biogas composition.

However, one of the major drawbacks is to find suitable electrolyte with increased tolerance to biogas composition (CO_2, H_2S, etc.) since the current materials suffer from poor chemical stability. Therefore, the main objective of this study is related to the development of electrolyte materials that must offer increased chemical resistance against biogas feed while also being stable in contact with the remaining cell components. To this end, perovskite proton-conducting ceramics of the ABO_3 structure with the specific composition of $BaZr_{1-x}Y_xO_{3-d}$ (x = 0-0.2) family were synthesized using different processing methods: the acetate combustion route and the mechanosynthesis. Preliminary results show that the combustion route failed to obtain pure phase materials, yielding a mixture of Y-rich and Y-poor phases, which have possibly resulted from cross-substitution of Y^{3+} over A- and B-sites. Conversely, complete phase formation was obtained in the case of the materials produced by mechanosynthesis, which was demonstrated to be a highly promising synthesis route to produce proton-conducting perovskites.

The obtained materials are, thus, ready for subsequent chemical stability tests in biogas atmospheres, where its future integration in electrochemical devices offers a green pathway for syngas production with important applications in chemical industry.

Keywords — Ceramic electrolyzer; biogas; syngas; electrolyte.

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Development of High Temperature Proton-Conducting Electrolytes for Hydrogen Technologies

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***Abstract*— Proton conducting ceramics electrolytes have been extensively studied for application in hydrogen related technologies, such as, proton conductors fuel cells (PCFCs), hydrogen separation membranes, proton conductor electrolyzer cells (PCECs), or for the synthesis of value-added chemical products, such as, hydrogen, syngas (H_2 + CO) and ammonia. These technologies are expected to play a fundamental role in reducing CO_2 emissions by sustainable production of H_2 or industrially relevant chemicals. Perovskite materials based on the barium cerate and barium zirconate phases, doped with yttrium have been considered the most promising and have, thus, dominated the research on proton-conducting electrolytes. Although, Y-doped barium cerate materials exhibit higher total conductivities, they have been shown to be chemically unstable in H_2O and CO_2-containing atmospheres [1]. Conversely, Y-barium zirconate materials ($BaZr_{1-y}Y_yO_{3-\delta}$, BZY) are attractive as they combine high levels of proton conductivity with superior chemical stability in these conditions [2]. Nonetheless, their application has often been constrained due to processing difficulties and poor sinterability, requiring sintering temperatures above 1600 ºC to achieve full densification. In the current work we show that the use of mechanosynthesis, from stoichiometric quantities of oxide precursors, can be efficient in the preparation of BZY powders, Fig. 1, with nanometric size (crystallites of ca. 30 nm), which offer good densification (~90 %) and grain growth (~1 μm), with competitive electrical performance (total electrical conductivity of $BaZr_{0.85}Y_{0.15}O_{2.925}$, at 700 ºC, in wet 10 % H_2/N_2, of 5.66 mS/cm) [3,4].**

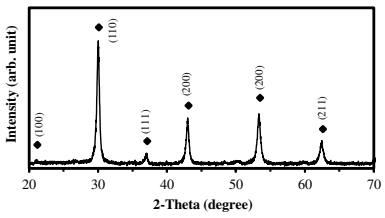

Fig. 1. X-ray diffraction pattern of $BaZr_{0.85}Y_{0.15}O_{3-\delta}$ prepared by mechanosynthesis.

Keywords*— proton conductors; barium zirconate; mechanosynthesis

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Novel nanocomposites for energy storage

(Titania – activated carbon nanocomposite for high capaity hydrogen storage in MgH_2 and high density electric energy storage in an Li ion battery)

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***Abstract*— Development of high-capacity metal hydrides for the storage of hydrogen and development of high energy density rechargeable batteries for the storage of electricity are the two intriguing tasks in energy research, and the scientific community is stiving hard for achieving breakthroughs. There are only a very few materials that can be used for both applications, (i) promoting hydrogen storage in metal hydrides and (ii) improving Li storage in Li ion batteries. Our interest in the current study is to develop and test one such material, called titanium dioxide-activated carbon nanocomposite.**

Note that optimization of a hydrogen fuel tank with a gravimetric storage capacity of >5.5 wt.% H_2 is an important necessity for the development of green hydrogen vehicles [1]. In this context, various lightweight binary hydrides, complex hydrides and composites were investigated [2-5] and it is clear that presently magnesium hydride (MgH_2) is the only solid-state metal hydride that can consistently deliver the required amount of H_2 over hundreds of cycles. Nonetheless, a notable setback is that the MgH2 system is operational at temperatures >350 °C which is much higher than the proposed working temperature, 85 °C. Therefore, to improve the performance of MgH_2 additives are necessary and several additives were already used by worldwide researchers, but no significant breakthrough has yet been achieved.

Similarly, several materials were also tested as active working electrode materials for Li ion batteries and the commonly observed issue is the degradation of performance after several cycles. This is because, during the repeated charge/discharge process, the volume change causes swelling issues and consequently, the detachment of particles from the main electrode and / or from the adjacent particles lead to loss of electrical contact.

Recently, in our lab we developed a novel nanocomposite ($0.2TiO_2$ + AC) which shows considerable promise for two different applications mentioned above (hydrogen storage and batteries). The surface area of activated carbon (AC): 491 m^2/g, pore volume: 0.252 cc/g, size of TiO_2 particles: 20–30 nm. Our transmission electron microscopy study provides evidence that well dispersed TiO2 nanoparticles are enclosed by amorphous carbon nets. A thermogravimetry-differential scanning calorimetry (TG-DSC) study proves that the nanocomposite is thermally stable up to ~400 °C. Volumetric hydrogen storage tests and DSC studies further prove that a 3 wt.% of $0.2TiO_2$+AC nanocomposite as additive not only lowers the dehydrogenation temperature of MgH_2 over 100 °C but also it maintains the performance consistency. As a working electrode for Li ion battery, $0.2TiO_2$+AC offers a reversible capacity of 400 mAh/g at the charge/discharge rate of 0.1C and consistent stability up to 43 cycles with the capacity retention of 160 mAh/g at 0.4C.

The composite employed in the current study, $0.2TiO_2$+AC, was prepared by mechanical milling technique.

Keywords—Hydrogen Storage; Rechargeable Batteries.

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Technologies for the Wellbeing--Multiscale Technologies and Devices for Medicine, Environment & Energy

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Vanadium (oxy)nitride as a potential anode for ammonia solid oxide fuel cells

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Abstract — Ammonia (NH_3) is a promising energy carrier that can be used as a fuel in solid oxide fuel cells (SOFCs). Nevertheless, a challenge still remains for finding alternative anode materials, aiming to improve the durability/stability and the performance of the cell components [1-2]. In this sense, we developed a new composite anode material made of vanadium (oxy)nitride (VON) as electronic conducting phase and yttria stabilized zirconia (8YSZ) as oxygen ion conducting phase. The developed anode was fully characterized by diverse techniques such as X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), thermogravimetric analysis (TGA) and by Electrochemical Impedance Spectroscopy (EIS). The results revealed a good chemical compatibility between the both phases in reducing conditions (10 %H2-90% N2) at high temperature, 1150 °C. The TGA analysis showed that VON is stable under reducing conditions, showing a small mass change due to N/O ratio variation. The electrode mechanism under ammonia environment was assessed by EIS in the temperature range of 650-800 °C, and it was found to be similar to that of typical Ni-based cermets in hydrogen atmosphere. The polarization resistance, a key property that determines the electrode performance, was found to be highly dependent on the ammonia flow rate, increasing as the flow rate increases due to diffusion/gas conversion limitations. To the best of our knowledge, this work reports for the first time the use of vanadium oxynitride as anode for NH_3-SOFCs.

Keywords — VON, anode, ammonia, fuel cells

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Electrolysis for sustainable ammonia production

Electrochemical green ammonia synthesis as a potential hydrogen carrier

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***Abstract* — The REPowerEU plan aims to diversify the European sources of imported fossil fuel and to accelerate the development of renewable fuel imports, through the creation of supply corridors. This is the case of hydrogen, where the plan foresees the yearly production of 10 Mton of renewable hydrogen with 65 GW of electrolysis capacity [1]. To achieve this goal, there are still several challenges to be addressed regarding storage and distribution of hydrogen. In this regard, a potential hydrogen carrier is that of ammonia (NH_3), which is easy to liquify at relatively low pressure (1030 kPa) at ambient temperature, whereas hydrogen liquefaction cannot be realistically formed in such conditions. In addition, the energy density of liquified ammonia (11.5 GJ m^{-3}) is significantly higher than that of gaseous (2.1 GJ m^{-3}) or liquid (8.1 GJ m^{-3}) hydrogen, and even surpasses that of compressed natural gas (10.4 GJ m^{-3}) [2].**

However, the industrial ammonia (NH_3) production (Haber-Bosch) has a very high energy consumption, low efficiency (10 – 15%), and produces 300 million metric tons of CO_2 per year due to its continued reliance on hydrogen from natural gas. Therefore, this study offers an alternative solution for ammonia formation by using a ceramic electrolyzer to directly synthesize this chemical compound from renewable sources, including water and nitrogen (from air). The proposed technology offers the important advantage of operating at ambient pressures (1 atm), thus, requiring significantly less energy with respect to the Haber-Bosch. This benefit is complemented by operating at intermediate temperatures (i.e., 400 – 500 °C), which facilitates the endothermic steam reforming reaction. Conversely, the ammonia formation reaction is exothermic, where integration of these two processes in one device can facilitate overall heat integration, reducing the primary energy demand. The remaining necessary energy input can be provided from joule heating using renewable energy sources (e.g., solar, wind, etc.).

However, current limitations are to find suitable electrocatalyst materials since the current ammonia formation rates and Faradaic efficiencies are still below the necessary targets for industrial application, i.e., ≥ 10-8 mol s-1 and ≥ 10 – 15 %, respectively [3]. Therefore, the main outcomes from this study are related to the development of novel electrocatalyst materials that must be selective for ammonia formation while also being stable in contact with the remaining cell components. This project offers a highly promising and potentially disruptive route to synthesize one of the most important chemical compounds extensively used worldwide.

Keywords — Ceramic electrolyzer; ammonia (NH_3); hydrogen (H_2); electrocatalyst.

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Molten salt synthesis of MAX phases

Preparation of Ti_3AC_2 (A = Al, Si) powders in argon and air

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Abstract — **Energy-related applications are an area of critical importance as we strive to develop sustainable and efficient solutions to meet our growing energy demands. Materials science plays a crucial role in the development of these solutions, as new materials with tailored properties can lead to breakthroughs in areas such as energy conversion, storage, and transport. In this regard, $M_{n+1}AX_n$, or MAX, phases are highly useful materials due to their unique combination of properties and versatility, filling the gap between ceramics and metals. They consist of layers, with a hexagonal crystal structure (space group P63/*mmc*). Regarding the general formula, "M" corresponds to a transition metal, "A" to an A-group element, "X" is carbon or nitrogen, and "n" is equal to 1, 2, or 3, which represents the number of "M" layers separating the A layers. The MAX phases exhibit good mechanical, magnetic and electrical properties, as well as increased oxidation resistance, making them suitable for a wide range of applications such as structural materials for high-temperature applications, protective coatings, electrical contacts, catalysts, amongst others [1].**

There are more than 150 different compositions in this family of materials. Among them, Ti_3AlC_2 and Ti_3SiC_2 are promising compositions due to their higher stability in a wide range of temperatures and higher electrical conductivity, compared to Ti metal itself (>10,000 S cm^{-1} *vs.* ~5,500 S cm^{-1} at 1,000 K), presenting metal-like electrical conductivity. When compared with other MAX phases (V_2AlC, Ti_2AlC, Nb_2AlC, Cr_2AlC), the Ti_3AlC_2 and Ti_3SiC_2 materials offer superior electrical conductivity at 300 K. Moreover, these systems also possess thermal expansion coefficients of around 8-10 x 10^{-6} K^{-1}, thus, also being good candidates for conventional Thermal Barrier Coatings (TBCs) [1,2].

Another important property of these materials is their resistance to oxidation in air. Wang and Zhou [3] demonstrated for the Ti_3AlC_2 composition that oxidation started at 600 °C, including two modifications of TiO_2 (*i.e.* anatase and rutile) and Al_2O_3. A similar trend was also observed by Pang *et. al.* [4], but with the oxidation mechanism starting from 500 °C. The oxidation of Ti_3SiC_2 also results in formation of a TiO_2 matrix in which an inert phase (SiO_2) precipitates. These alumina and silica layers provide protective coatings to permit continued utility above 900 °C for extended time periods [2]. Nonetheless, their application in the temperature range between 500 °C and 900 °C is compromised under high oxygen partial pressures and, thus, their usage in other atmospheres must be explored.

Some of the challenges inherent to these materials are related to obtaining pure phase compositions, thus, restricting their transference to industry [1]. Therefore, in the current work, we aim to address this problem by exploring alternative synthesis routes of different MAX phases. Here, Ti_3AlC_2 and Ti_3SiC_2 are synthesized by two different approaches based on the molten salt synthesis. A NaCl-KCl eutectic salt and a KBr salt are used in argon and air for the synthesis at different temperatures (1000 – 1350 °C). As a promising route, KBr is used for gas-tight encapsulation for further high temperature processing in air. From this methodology, 94 wt.% Ti_3SiC_2 is obtained at a synthesis temperature of 1350 °C.

Keywords* — *MAX phases; Synthesis; Molten salt; Ti_3AlC_2; Ti_3SiC_2.

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A layered double perovskite as potential electrode for protonic ceramic electrochemical cells: Ba2NiMoO6-δ

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***Abstract* — Perovskite based materials, namely, double perovskites ($A_2BB'X_6$) are gaining special interest as electrocatalysts, due to their good chemical stability, high electronic conductivity and high electrocatalytic activity for the oxygen evolution, oxygen reduction and hydrogen evolution reactions [1,2].**

In this work, $Ba_2NiMoO_{6-\delta}$ (BNMO) composition has been explored as an electrode to be used in the intermediate temperature range (400-600°C) in protonic ceramic electrochemical cells. Experiments were performed to study the chemical stability and compatibility as well the electrical properties.

BNMO composition reveals to be stable in oxidizing (O_2, N_2) and reducing ($10H_2$-N_2) conditions at temperatures below 600 °C. In contrast, in carbonaceous atmospheres the perovskite BNMO phase is shown to decompose into barium carbonate ($BaCO_3$) and barium molybdate ($BaMoO_4$). Compatibility results shows that at temperatures below 1100 °C no inter-reaction occurs between BNMO and $BaCe_{0.7}Zr_{0.1}Y_{0.2}O_{3-\delta}$ (BCZY712) protonic electrolyte.

The screen printing method was used to prepare symmetrical cells of pure BNMO and composite of BNMO-BCZY712 (50/50 vol%) which were studied by using electrochemical impedance spectroscopy in wet O_2 (pH_2O=0.03 atm) in the temperature range 600-400°C. Results reveal that the pure BNMO sample shows a better performance than the composite (BNMO-BCZY).

To the best of our knowledge, this is the first study of the layered BNMO double perovskite for proton conducting applications.

Keywords*— protonic ceramic electrochemical cell, double perovskite, electrochemical impedance spectroscopy (EIS).

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Fabrication of anode-supported thin film electrolyte membranes for Solid Oxide Fuel Cells

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***Abstract* — The development of thin film electrolyte membranes for fuel cells and electrolysers is a key part of the "Strategic Research and Innovation Agenda 2021-2027" that aims to tackle climate change [1]. Within this plan, our goal is to design fast ionic conductors to be used as electrolyte membranes that can operate at the intermediate temperature range (*e.g.*, 500 – 600 °C). Gadolinium-doped ceria (CGO) has become one of the most widely used electrolytes for application in Solid Oxide Fuel Cells (SOFCs) [2]. This material can be a promising alternative to the state-of-the-art zirconia-based electrolytes, which typically require higher operation temperatures (*i.e.*, 800-1000 °C) [3].**

The fabrication of thin CGO electrolyte films, however, has been a challenge, mainly due to the difficulty in producing fully dense films [4]. Our goal is to optimize the fabrication of dense thin electrolyte films, with thickness below 40 µm, with the composition ($Ce_{0.90}Gd_{0.10})O_{2-d}$ (CGO_{10}) on porous cermet NiO-CGO_{10} electrode substrates. A secondary, but important objective, was to guarantee a good homogeneity of the NiO-CGO_{10} cermet electrode. Three different methods were tested: spin-coating, screen-printing, and hand-brushing, followed by a sintering step in air. The density and thickness of the films were then evaluated using scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS). In all cases, a good adhesion of the CGO_{10} electrolyte to the NiO-CGO_{10} cermet was observed.

Nonetheless, several differences were identified with respect to the microstructure of the produced films. The main results reveal that, among the three techniques, spin-coating produced thinner films, of around 9 µm in thickness, albeit not fully dense. In the case of the screen-printing methodology, thicker but non-uniform films with a 45-80 µm thickness were produced. Finally, the films deposited by paint-brushing were successfully densified, with a thickness of 30-40 µm. Cross-sectional SEM and EDS images showed that these results may serve as basis for further optimization and refinement of the deposition techniques being used.

Keywords — Solid Oxide Fuel Cell (SOFC), gadolinium-doped ceria (CGO); electrolyte; electrochemical cell; thin film deposition.

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O_2 and CO_2 electroreduction in solid oxide cells

Electrochemical performance of the promising $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}$ electrode

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***Abstract* — Global warming has led to several climate changes, with carbon dioxide (CO_2) emissions being the main cause. Reducing such emissions by generating clean energy is the best way to mitigate this damage. In this way, Solid Oxide Cells (SOCs) are promising electrochemical devices because they can operate both in fuel cell and electrolysis modes, converting H_2 into electrical energy and water, or, conversely, power to fuel, respectively. Likewise, it is also possible to reduce CO_2 to produce valuable synthetic chemicals [1].**

One of the main limiting factors affecting the overall performance of SOCs is related to the electrical polarization losses of the electrode components, which should be minimized. In this regard, molybdenum-doped strontium ferrite, of composition $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}$ (SFMO) presents good mixed ionic-electronic conductivity (MIEC) properties, in addition to being stable in oxidizing and reducing atmospheres [1]. Therefore, SFMO is a good electrode candidate for both modes of operation (fuel cell and electrolysis). However, the current polarization resistance, R_{pol}, values must be decreased to leverage the SOC technology into the energy conversion chain.

For this reason, in this work, we aim to improve the O_2 and CO_2 reduction reactions by the addition of an ion-conducting interlayer with a minor p-type electron conductivity, $Ce_{0.8}Pr_{0.2}O_{2-\delta}$ (CPO), between the SFMO electrode and electrolyte. The aim is that these mixed transport properties of CPO can significantly increase the surface-exchange pathways, minimizing potential losses associated with diffusion and surface polarizations [2-4]. With respect to the SFMO electrode thickness' impact on polarization behavior, the electrochemical performance of SFMO/$Ce_{0.9}Gd_{0.1}O_{1.95}$ assemblies was initially assessed by Electrochemical Impedance Spectroscopy (EIS) in the temperature range of 600 – 800 °C.

A minimum R_{pol} value (~0.4 Ω cm², at 700 °C, p_{O2} = 1 atm) is found for the sample with a thickness of around 43 µm (6 depositions). We suggest that the better performance observed when increasing the number of depositions is related to the higher solid volume of material close to the electrolyte surface region, which can promoted better ionic conduction and, thus, improved electrochemical reaction. This result is extremely important, as it can provide insight into future new optimization methods for electrodes used for the reduction of oxygen and carbon dioxide.

Keywords*— $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}$ (SFMO); Solid Oxide Fuel Cell (SOFC); Solid Oxide Electrolyzer Cell (SOEC); CO_2 electroreduction; active layer; microstructure.

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Smart water supply systems operation with optimization strategies and analytical sensitivity approach

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***Abstract*— Drinking water is an essential commodity for the survival of human society. Although just a small fraction of the Earth's surface water, 2.5%, is freshwater and suitable for consumption. To deliver this drinking water, Water Supply Systems (WSS) are used to transport it from the source to the population [1]. This transportation process requires a considerable quantity of energy, particularly to hydraulic pumps, which corresponds to 35% of the total expenses [2]. For example, in Portugal with 10 M inhabitants the pumping energy consumption is more than 644 GWh per year [2]. The current operation of WSS is not full-efficient due to poorly planned strategies in pumping stations, as it does not take into consideration factors such as electricity prices, variable-speed pumps or water demand at different times of day and seasons. To improve the efficiency of WSS, the use of hydraulic models and optimization algorithms can provide valuable insights for operation and management, especially when combined with an effective sensitivity analysis.**

This work aims to develop an expedite methodology for solving the energy-efficient operation of WSS with a cost-effective solution, focusing on reproducing and analyzing hydraulic systems using several optimization algorithms, including gradient-based methods with analytical sensitivity analysis. For the latter case, this work compares the sensitivity computation based on an analytical formulation with the approximate finite difference method for two numerical case studies: a simple network and the AnyTown Modified benchmark [3].

As expected, the analytical calculation of the derivatives can present more accurate results, without having to resort to high computational resources, since it does not require multiples evaluation for a single sensitivity analysis, making it the main advantage and asset.

Keywords — Water supply system; Energy efficiency; Operations; Optimization; Sensitivity analysis; Hydraulic modelling

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Machine Learning models for prediction and optimization of water supply networks

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***Abstract*— As society progresses, so does the demand for basic resources, particularly water, resulting in increased energy consumption for water distribution. Managing and distributing these resources efficiently has recently become a critical goal. Decision support systems (DSS) and hydraulic simulators such as EPANET, have been developed to optimize water distribution. However, these systems have limitations, such as high computational costs and calibration complexity. Smart predictive control models that use advanced technologies such as machine learning algorithms have been developed to overcome these drawbacks. These models can learn from data to achieve optimal water distribution control.**

This work analyses various machine learning model architectures, as for example [1], which won the NeurIPS 2018 Best Paper award. The Neural Ordinary Differential Equations (ODE) model is a deep learning approach that treats neural networks as continuous functions and solves them using ODE solvers. This approach has shown promising results in various applications, including image generation, time-series modeling, and physics simulation. In this study, this technique is applied to predict and optimize water distribution, being then compared to other models.

Three case studies utilizing supervised learning models are here trained and validated on historical water usage data to evaluate their ability to make accurate predictions compared to EPANET. Additionally, the study is used to optimize pump control schedules using energy price variation to reduce operational costs.

The outcome of this research is a faster, more accurate, and less expensive model for water distribution. These findings benefit water utilities and other stakeholders in the water industry, enabling them to select the most appropriate solution for their specific needs. Furthermore, the study contributes to the academic community by demonstrating the use of machine learning in smart water systems and the development of more advanced and effective water distribution technologies.

Keywords*— *Water distribution systems; Pump scheduling; Machine Learning; Optimization

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Pump-storage optimization in Water Supply System: A case study

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***Abstract*— Environmental sustainability has been increasingly present in our daily lives. Investments in renewable energy sources such as solar, wind, geothermal, or hydroelectric energy are increasingly a clean and viable alternative paradigm shift.**

The majority of developing countries have the highest operational costs in water supply systems (WSSs), where there is an increase in demand for water. The electricity consumption due to the water pumping represents the highest proportion of the energy costs in these systems.

Pumped Hydro Storage (PHS) is the most widely implemented mechanical energy storage system with a high storage capacity and long-term efficiency. The main purpose of a PHS system is to store gravitational potential energy and recover it in electrical energy. Typically, this energy-type transformation is carried out by means of turbines. Currently, this type of system is a mature and commercially available technology.

The objective of this work is to evaluate the potential use of these energy recovery systems to increase the operational and financial efficiency of water supply systems. In this way, it was developed an optimization model of PHS operation considering the new paradigm of energy price variation throughout the day. The developed model was applied to a case study, evaluating the economic and operational benefits regarding the use of PAT instead of a pumping system. "

The developed model estimates the sensitivity of an energy recovery system in water supply systems in different scenarios. Predictably, its viability is proportional to the size of the system, that is, the greater the storage capacity, the greater the energy, and its financial return. Regarding cost savings, the model can assess the complementarity between market energy prices and the need for energy recovery to determine its operating range.

This integrated approach to energy storage and water supply can be a viable, long-term solution to the challenges associated with managing water and electrical resources.

Keywords*— *Water supply systems; Energy recovery; Pump storage; Time-differentiated tariffs; Operational optimization;

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Enhancing Water Supply Systems operations with Smart Predictive Digital Twins and Real-time Orchestration in Multiservice Frameworks

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***Abstract* — Water supply systems (WSS) are critical infrastructures in society, tasked with providing a reliable and safe supply of water. These systems implement pump schedule operations to meet water demand while respecting hydraulic constraints (e.g., maintaining adequate pressure in the water distribution network). Modern disruptions, such as aging infrastructure, climate change, and energy cost uncertainty, can be responsible for the cost increase of pumping operations. This work proposes a digital transformation for WSS to achieve cost-effective pump scheduling operations.**

Digital twins have recently emerged as powerful tools for creating virtual representations of complex real-world systems in the digital space. This technology is promising for emulating and predicting WSS's hydraulic states and has already been applied to water leakage control [1], and prediction of the system's performance [2]. Hydraulic simulators, such as EPANET, have been used to model WSS. However, their calibration is still time-consuming. Alternatively, data-driven models do not require calibration and, therefore, can be easily used instead.

In this work, a smart predictive digital twin (SPDT), working as a model predictive control algorithm, is used to minimize the cost of pump scheduling operations. The proposed framework operates in real-time and is designed as a multiservice architecture, where each service works independently, but collaboratively to achieve a global goal. Each service is modeled by machine learning techniques, resulting in different data outputs, such as energy costs, water demand forecasts, and WSS hydraulic state predictions. The SPDT's operation is improved by incorporating this data.

The proposed system uses multiple non-exact data sources that propagate error/uncertainty throughout the system. To overcome this problem, the framework has a global orchestration module that is responsible for monitoring and managing the data streams from all the modules, ensuring their reliability.

The main contributions of this work are the development of a state-of-the-art efficient pump scheduling framework, and the implementation of a real-time orchestrator to correct module uncertainties/errors, thereby improving system decisions. This work also evaluates the impact of the accuracy of each module on the performance of the overall system.

Keywords— Digital Twins; Water Supply Systems; Forecasting; Multiservice Frameworks; Model Predictive Control; Machine Learning; Dynamic Orchestration

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Sustainable mobility in an ERASMUS student context

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Abstract— **Nowadays, it is increasingly notorious the need for people to travel for any activity they practice, whether in the area of leisure, or a simple shopping trip or even a trip to the workplace. The university students in Europe have the possibility to spend one semester or one year of their studies in a foreign country. Thus, the objectives of this work are: 1) to characterize the trips made by ERASMUS students who will study at the University of Aveiro; 2) to evaluate the various modal share options between the cities from which the students are coming from and Aveiro and quantify the associated emissions, and 3) to evaluate the implementation of integrated measures of smart and sustainable mobility (namely with public transport, shared mobility, energy transition and digitalization) and the respective effects on the carbon footprint.**

Emissions related to the mobility of Erasmus students at the University of Aveiro will be calculated using Copert program [1]. A survey will be distributed to all these same students so that they can share details about their daily mobility options.

This work is part of the EASEM project (Erasmus Sustainable Mobility), which is part of the SMART-ER Seed Programme (collaboration between universities of the ECIU consortium) [2]. This project includes the participation of three different universities, the Autonomous University of Barcelona (Spain), Aalborg University (Denmark) and the University of Aveiro (Portugal). It is known that the target students of this study will have a more significant carbon footprint during their stays abroad than when studying in their home city, but, on the other hand, it is also known that most international students will use, with some frequency, public transport, bike-sharing systems, among other sustainable mobility options, which will balance the ecological footprint [3].

Keywords*— *International students; Erasmus mobility; Greenhouse gas emissions; Transports; Carbon footprint.

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Assessment of Noise and Exhaust Emissions Hotspots through Advanced Techniques

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***Abstract* — This communication aims to present the evolution of the Ph.D. project entitled "An Integrated Assessment of Road Traffic Noise and Pollutants Critical Hotspots through Advanced Models" which involves the formal collaboration between the DEM/TEMA of the University of Aveiro, Portugal, and the Civil Engineering Department of the University of Salerno, Italy.**

The plan includes the development of a novel Noise Emission Model (NEM), denominated Vehicle Noise Specific Power (VNSP) [1,2]**, able to assess the sound power level (L_w) for passenger cars mainly based on speed and motorization. The VNSP has been developed in the first stage of the Ph.D. program, and together with other NEMs, has been, then, coupled with a sound propagation model, following a modular approach, leading to the development of microscopic Road Traffic Noise Models (micro-RTNMs) able to assess the equivalent continuous A-weighted sound pressure levels (L_{Aeq}) at any receiver point and temporal basis.**

Data collection was performed to calibrate the VNSP model in different locations (a flat and a hilly road in Aveiro, and a track in Battipaglia, Italy), by using a total of seven probe vehicles, chosen based on the common motorizations present in Europe (two diesel-powered, two gasoline-powered, two hybrid-electric, and one LPG-powered). Thus, two different approaches were followed. Firstly, the VNSP was coupled with a sound propagation model, creating a particular type of RTNM able to consider: i) the vehicle motorization; ii) the hourly traffic volumes by lane; iii) the hourly average speed by lane; iv) the acoustic energy directed to the receiver point during the pass-by of each vehicle. This approach was tested and validated through data gathered from a radar and a noise sensor installed on a major road in Aveiro. The information from the former was used as an input for the RTNM, while the estimations of this last one were compared with the noise levels recorded by the sensor. Results showed that the RTNM commits an average error of around 3 dB(A) [3]**. Secondly, VNSP was substituted with existing NEMs present in the literature, and the sound propagation model was modified to consider in input the speed of each on-road vehicle. Data in terms of traffic volumes and speed were extracted from videos recorded on a rural road in Aveiro and used as inputs for the RTNMs. The estimated noise levels were, then, compared with those recorded with a sound level meter to confirm the goodness of the developed approach. It was found out that the average errors committed by models are lower than 1 dB(A).**

Keywords— Noise Modeling; Vehicle Noise Specific Power; Road Traffic Noise Models.

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Development of an integrated driving volatility-safety--emissions indicator for highways

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***Abstract*— Road safety levels can be improved through a good characterization and understanding of driving behavior. Volatility can be seen as an extension of driving behavior, being associated with acceleration/braking, vehicular jerk (the first derivative of acceleration), unusually high speeds, and lane-changing maneuvers [1]. The volatility in driving can be associated with different driving patterns which in turn may impact on emissions generated by road traffic [2]. Thus, it is important for drivers to assess their driving styles to become aware of how much they are contributing to road traffic emissions. There are some studies that focus on the analysis of driver volatility incorporating emissions [3]. However, there are no studies with an indicator that integrates driving volatility with safety and emissions-related impacts. Hence, the objective of this work is to build an integrated indicator that evaluates driving behavior on highways based on safety (time headway, stopping distance), volatility (acceleration and vehicular jerk), and emissions (Vehicle Specific Power mode -VSP) components. The driving indicator was built through a linear optimization problem with linear constraints and lower bounds and then solved in MATLAB software. To validate our application the microscopic traffic model VISSIM with a COM API interface was used. The model was calibrated using tailpipe emissions, vehicle dynamics, and traffic data collected from test vehicles on three highways: A25, A29, and A1. A total of 97 trips were assessed in this study. For each variable used to define safety, volatility, and also for VSP mode, the failure in percentage for each trip was computed. Failures were defined using thresholds from the literature. After that, the score of each trip was computed and driving behavior was classified. Results indicated that 29%, 19%, 13%, and 39% of the drivers were classified as calm, normal, aggressive, and very aggressive, respectively.**

Keywords*— *Integrated driving indicator; Safety; Volatility; VSP mode.

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Forecasting passenger flow in the Lisbon Metro under football events based on multiple match information data

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Abstract— **In urban mobility, many special events, including cultural and sports, often represent challenges for the efficient management, operation, and attractiveness of public transport, namely the metropolitan systems. One of the key strategies for achieving an efficient management metropolitan system is the subway passenger flow prediction under these events in order to adequate supply to demand. These adjustments can be achieved by considering historical and real-time information of different variables associated with the events to build an important mechanism for future operations adjustment by the operator. Previous studies have developed models to improve flow forecast at subway stations (1) to handle the increase of passengers during sports events, such as tennis, baseball, or football. However, the use of specific variables related to the competition type, opponent, team form, position in the competition, result during the different phases of the match, hour, day of the week or weather conditions is still scarce. Based on a collaboration protocol with Lisbon Metro, this study focuses on developing a forecast flow model to predict the temporal demand in the subway stations that serve the football stadiums of Sport Lisboa e Benfica (Benfica) and Sporting Clube de Portugal (Sporting) during football events. This study uses attendance values and predicts ridership before and after the match from that attendance based on time-series modelling. The specific objective of the study is threefold: 1) to evaluate metro demand (number of validations, number of vehicle compositions, origin-destination matrices, load of compositions) at three subway stations during the football matches of Benfica and Sporting; 2) to examine the impacts of a set of variables in what respects the attendance, competition type, opponent, team form, position in the competition, result at half-time, 15 minutes before the end of the match, and in the end of the match, hour of the match, day of the match, , temperature, presence of rain and wind on the mobility data; and 3) to develop and validate a forecast demand model able of predicting passengers flow during the sports events. Sports data were collected from 104 and 96 matches of Benfica and Sporting, respectively, between 2017 and 2023. Our first results indicated that there are statistical differences in attendance medians based on Kruskal-Wallis test for the competition type and opponent variables in both teams, as well as, for wind and rain variables in the attendance of Benfica and Sporting, respectively. Next steps will be focused on the relationship among variables with demand and passenger flow, as well as in correlating these variables and subway passenger flow modelling in time-series prediction.**

Keywords: Sports Event Management; Football Events; Mobility Data; Subway Passenger Flow Prediction.

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Impacts of Fuel Cell Buses under a Life Cycle Perspective

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***Abstract*— According to the Paris Declaration on Electro-Mobility and Climate Change & Call to Action transportation contributes almost one-quarter (23%) of the current global energy-related greenhouse gases emissions and is growing faster than any other end-use sector. [1] Alternative vehicles are currently being promoted rapidly by automotive industry. On the other hand. bus fleets represent the core of the road public transport sector. There are above three million city buses in operation worldwide and the growing concern about the emissions from internal combustion engines impels the development of new energy sources to replace or reduce conventional nonrenewable energy usage. [2] One of the most energy vectors studied nowadays is hydrogen. Which is found to be a promising solution for the transport sector. [3] When used in fuel cells, hydrogen produces only water as a by-product and can be considered an alternative to fossil fuels. [4] Many countries are announcing hydrogen strategies or plans and more developing them, defining a critical role for hydrogen in achieving and energy system with net-zero emissions. [5]**

The main objective of this research is to implement Life cycle assessment (LCA) of a specific fuel cell bus (H2. City Gold – Caetano Bus) fabricated in Vila Nova de Gaia, Portugal, and operating in many countries in Europe. An inventory of the vehicle will be created related to the production, use and end-of-life, and with the detail information, SIMAPRO software will be used. LCA is a recognized methodology for evaluating the environmental impacts of a system or a product over each phase of its complete life cycle. After the reference scenario, several alternative scenarios will be tested, namely the potential of a hydrogen automated bus.

Keywords— Hydrogen; Fuel cell bus; Life cycle assessment.

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Exploring operational and energy-environmental performance using a driving simulator

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***Abstract*— The increase in private vehicle ownership entails some adverse impacts on the road transport system, such as congestion, accidents, and traffic-related emissions. Such impacts can be largely related to driving behavior [1], [2]. Studies focusing on exploring driver's behavior are relevant for a better understanding of its influence and its impacts, aiming to support the definition of strategies and measures that provide an improvement in environmental aspects and road safety. Driving simulators experiments present the advantage of having no risk of accidents and not producing pollutant emissions. Additionally, this type of tests also allows to establish specific scenarios and collect large amounts of data that can be used for conducting in-depth studies.**

Following previous works [3], [4] the proposed study is devoted to exploring driving behavior characteristics when facing different urban scenarios. Concretely, this work aims to examine how the use of a manual and an automatic transmission vehicle can affect the driver's behavior. This analysis focuses on different domains, such as operational and safety performance and associated impacts on the estimated vehicle's fuel consumption and emissions. The tests will be conducted with several volunteers and involve different test scenarios. Driving tests in a simulated environment will mostly take place in an urban environment due to their complexity regarding road singularities and the presence of vulnerable road users (pedestrians and cyclists). The simulator software will allow us to define scenarios and collect in-vehicle parameters, such as instantaneous speed, acceleration, RPM, and accelerator/brake pedal position, among other variables. This data will allow us to estimate other relevant variables such as vehicle-specific power, stopping distance, and explore driving volatility and consequent pollutant emissions and fuel consumption. The results should contribute to a better understanding of the driving task.

Keywords*— *driving behavior; transmission type; emissions; fuel comsumption; driving performance.

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Design and evaluation of MaaS bundles in the regions of Aveiro and Coimbra

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***Abstract*— The transport sector is responsible for consuming around 30% of the European Union's (EU) total energy [1], representing a large share of greenhouse gas (GHG) emissions. Moreover, road transport is responsible for around ¾ of GHG emissions in the sector [2]. Therefore, a change in this sector is critical to achieving the EU Green Deal targets.**

Being considered a promising solution for more sustainable travel behaviour, Mobility as a Service (MaaS) aims to provide integration between different transport operators with the ambition of a more sustainable transport system [3]. MaaS services can be offered through MaaS bundles, which are subscription plans that combine various transport modes into a single mobile platform. However, when reviewing the evaluation of MaaS pilots and their impacts, it is clear that the conducted studies are centred on large-sized cities in which public transport (PT) systems are well-developed [4, 5].

This study proposes an approach to designing and evaluating MaaS bundles by examining the potential of a regional-driven MaaS subscription plan. In this work, specific analyses arising from stated preference surveys launched on two different cities in the Centro Region of Portugal, namely Aveiro and Coimbra, were conducted to characterise user intentions in adopting the proposed MaaS bundles and to evaluate the associated impacts in terms of carbon dioxide (CO_2) and nitrogen oxides (NOx) emissions. The results point to a preference for bundles that offer unlimited travel on PT. Due to the higher coverage of the PT network in the Coimbra region, in this region, 72% of respondents showed a willingness to use the bundles, while in the Aveiro region, the intentions to use were 62%. An analysis of the impacts of the bundles on gas emissions indicates a reduction of up to 90% in CO_2 and 68% in NOx emissions in the optimistic scenario while considering a more realistic yet limited scenario, there were found emission savings, on average, of 50% for CO2 and 45% for NOx emissions. The study demonstrates that simple changes in travel habits, such as a shift from private cars to PT or smooth mobility, due to the availability of MaaS bundles strongly affect the negative travel impacts.

Therefore, to maximise the impact of MaaS, it is vital to invest in the optimisation of transport networks, improve passenger information systems, and increase the frequency and quality of PT. MaaS may support connecting places by integrating different transport modes into a single service; however, this concept walks along with PTs as these are the backbone of the proposed bundles.

Keywords*— *Mobility as a Service; MaaS bundles; multimodal transport; stated preference survey; emissions.

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Comparative analysis of metro system data in different European cities

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***Abstract*— An efficient (public) transport system is fundamental for society and economic development. In large cities, the metro system is an integral part of the public transport system and it is becoming increasingly important to provide an efficient service at various levels (users, operators, investments), to meet the mobility needs of users [1]. In order to achieve more sustainable mobility, attracting new users to the public transport system, in particular to the metro system in large cities, is crucial to reduce the dependence on private car use [2][3].[Disruptions (e.g., mobility restriction measures, adverse weather conditions, service outages and special events in a city) may interfere with mobility patterns, changing the demand for transport services according to the needs of the moment, sometimes generating service constraints, and can potentially affect, for instance, the metro arrival/departure times, impacting users' needs. Passenger flow prediction of any metro system is an important component of intelligent transport systems, and plays a key role in supporting decisions regarding metro management and planning [4]. Information for managers, operators and users of the metro system is important to improve service provision and user satisfaction. For the service to be flexible, efficient and sustainable, accurate identification of mobility patterns in both temporal and spatial terms becomes relevant. The assessment of demand and supply (e.g., in real-time) at each metro station remains an important issue in the context of smart cities and is therefore, an area of constant study and development of improvements [5].**

The work proposed in the dissertation will consist of a comprehensive review of the characterization of the metro systems in different European cities (e.g., Lisbon, London, Bucharest). In particular factors found to influence performance will be described. Given the specificities of each city, a detailed study will be carried out based on historical data on supply and demand, as well as innovations implemented over time, to assess the potential impact of each of these different systems in terms of efficiency and sustainability. The core idea of the study is to increase knowledge and understanding of the different approaches and strategies implemented and their impacts, building a basis for decision support for discussing alternatives for different operations, investments, and decisions to better match supply to demand. The methodology developed will be important to support the analysis of sustainable transport policies, as well as to anticipate impacts and improve control strategies of metro system operations as a service. For this purpose, we will study in detail the metro system networks in each city, ticketing data (15 min intervals) for a more robust analysis of the in-flow and out-flow at different metro stations, service strategies and timetables in a daily and weekly pattern, and train distribution models over a period comprised between 2017-2022. The analysis will involve an exploratory component and parameter estimates to assess the impact on the efficiency of metro service in each city. One of the objectives includes estimating emissions of pollutants like CO2 and energy-related costs over the period selected for study.

***Keywords*— Metro system ; Metro performance factors; Delay determinants.**

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Development of a driving discomfort indicator using a vehicle driving simulator

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***Abstract*— Driving behaviour can influence various fields from GHG (Greenhouse Gas) emissions to road safety itself. The fleet of passenger cars in the EU has increased by approximately 6% between 2000 and 2019. The main factor contributing to this issue was the 16% growth in passenger transport volumes which represent more than 50% of the total road emissions [1], with significant impacts also in terms of road accidents and traffic injuries and deaths. Also, in terms of public health, it is estimated more than 40000 premature deaths due to nitrogen oxides (NOx) in Europe [2]. Thus, examining how drivers react to certain stimuli, such as different road geometries, and driving conditions and understanding drivers' behaviours is very important to support the definition of strategies to improve road design and city planning with major concerns related to improving air quality and safety and minimising carbon dioxide (CO_2) emissions. Furthermore, an often-neglected component of studying driver behaviour is related to the driver's comfort. Considering that on-road data experiments have some shortcomings, namely related to safety and environmental issues, the use of driving simulator experiments can provide large amounts of data and flexibility in designing road traffic conditions, avoiding the negative impacts of a real test. The main objective of this research is to create and scale a driver comfort indicator. For achieving this goal, a driving simulator will be used, and a selected sample of volunteers will be subject to a set of pre-defined road conditions. While performing this task, specific variables will be measured. These variables include the monitorization of drivers' heart rate, and the remaining variables are related to the vehicle dynamics, such as speed, acceleration, vehicle-specific power, as well as pedal information. The data will be collected on a second-by-second basis, so that a microscopic analysis can be performed. The case study will involve driving in an urban environment focusing on two different transmission types: manual and automatic. Therefore, specific variables will be explored to establish relationships and identify patterns that possibly may correspond to particular comfort states. Each driver will be subject to multiple runs of the same scenario to prevent runs with errors or anomalies. The data acquired will be treated and analyzed in order to estimate the emissions of CO_2 and NOx, vehicle-specific power, safety distances, etc. For obtaining the results, various methodologies will be applied, in particular, the VSP (Vehicle Specific Power) will be fundamental to assess the operating mode and pollutant emissions. For assessing driving volatility, the variation of acceleration will be computed. The most pertinent relations will be analyzed further linking the stimuli of certain events/situations to the driver's response under various components. These results will be a relevant contribution to traffic authorities, local and regional governing bodies in the definition of strategies to control and project road systems and policymaking.**

Keywords*— *Mobility, Driving Simulator, Emissions, Heart rate, Comfort

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The relevance of validation in the simulation of road conflicts between motor vehicles and vulnerable users

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Abstract— **In recent years, interest in new means of transport has increased, namely micromobility. However, the introduction of new means of transport is complex and requires some work because existing infrastructures and habits do not easily accommodate them, which can lead to conflicts between several types of transport [1]. The use of e-scooters to perform short-distance trips has shown great potential to help alleviate traffic congestion by reducing many journeys made by vehicles.[2]. The protection of the most vulnerable users (pedestrians, cyclists and other two-wheeled vehicles) and a safer road infrastructure are pointed out as two of the main road safety strategies. In 2021, there were 289 accidents caused by scooters, 244 minor injuries and 7 seriously injured being the year with the most incidents. Therefore, according to the National Road Safety Authority (ANSR), there was an increase in accidents in bicycles of 7.2%, comparing 2021 to 2022. Although "hit-and-run" and drunk driving are statistically similar to the causes of accidents involving pedestrians, there is also a significant death rate associated with traffic signs colliding with moving vehicles. [3]. Scooters can be more maneuverable and comfortable than bikes, although the former require longer braking distances. This study shows that different vehicles have different maneuvering restrictions; specifically, while a bike can be easier to slow down, a scooter is easier to drive. An obvious consequence for traffic safety is that the maneuver safer to avoid collisions may be different for a cyclist or for a scooter, even when the scenarios are identical [4].**

The main objective of this research is to simulate road traffic conflicts using traffic and safety microscopic tools and validate the output data with the experimental values recorded from Aveiro Tech City Living Lab in the city of Aveiro (Portugal), more specifically to evaluate the different types of traffic conflicts involving vulnerable roads users (VRUs) such as pedestrians, cyclists and scooter users in different traffic singularities located in urban areas. The case study will be specific intersections of the city of Aveiro, Portugal, where there is coexistence of motor vehicles with pedestrians, cyclists, and e-scooters users. After data collection and analysis using videotaping information recorded from Aveiro Tech City Living Lab, there will be traffic and safety modelling of the current traffic operations of the case study using the PTV VISSIM microscopic traffic and SSAM models, respectively.

Keywords—road safety; micromobility; risk behaviors.

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Developing public lighting solutions for light pollution reduction

A case study on portuguese territory

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Abstract – **The International Dark Sky Association, an NGO that works since 1988 towards the protection of the dark sky from artificial lighting, defines light pollution as the excessive or inappropriate use of artificial light [1]. The expansion of urban areas and the switch to LED technology has increasingly led to a higher intensity and more frequent use of artificial light, contributing to a rise in light pollution [2, 3].**

The relevance of this investigation unfolds with the underperforming rankings of Portugal's artificial light emission per capita, emission per GDP and average light emitted in its territories [3]. Data pointed to Portugal emitting four times more flux per capita than Germany [2] and being one of the European countries that most increased its illuminated area between 2012 and 2016 [3, 4]. Moreover, Portugal has the first site in the world to be certified as a "Starlight Tourism Destination, awarded to the Alqueva region by the Starlight foundation, supported by UNESCO, UNWTO and IAC, and has established cooperation protocols to establish the same certification for the Fajão village (Aldeias do Xisto) [5].

This establishes a scenario of demands and opportunities. It becomes increasingly relevant to reduce the excessive light at a national level, and to move towards recommendations justified by a scientific body that considers the impacts of light pollution in the observation of the night sky, biodiversity, health, and economy throughout the world, calling for its prevention [4].

This work begins with an investigation on the impacts of light pollution on the contemplation and enjoyment of the observation of the dark sky, assuming that this activity is intrinsically linked with the tourism development of the region, the enhancement of the scientific and technological systems, and the promotion of social and environmental sustainability, with a direct impact on the dynamization of the economy. By analyzing public lighting at a national level, potential opportunities for the improvement of luminaire design appear. By first raising awareness and contributing to municipal public lighting strategies, informing the potential gains generated by its adoption, measures can be applied for the improvement of light pollution levels. This can be achieved by utilizing solutions such as avoiding illuminating areas where or when light is not required, avoiding light above the horizontal level of the luminaire, and other solutions regarding the interdisciplinary integration of design and engineering for the development of new hardware solutions. At the same time, by using smart technologies to control the use and flux emitted by the luminaires, it is also possible to reduce energy consumption, increase efficiency and provide a better quality of life to both people and other beings [2].

Keywords— light pollution; ; luminaire; streetlight.

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Expanded Cork in Micromobility Helmet

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***Abstract*— Helmets are usually composed of an expanded polystyrene (EPS) liner with a polycarbonate (PC) outer shell. They are popular due to their low price and high impact absorption capacity. However, EPS's properties make it only capable to withstand one impact for the required energy level. In addition, when exposed to the environment, it can start to lose its performance. The CPSC (Consumer Product Safety Comission), for example, recommends replacing a helmet every 5-10 years (1). On top of this, the EN1078 standard further states that in the case of an accident, the helmet must be replaced, even if damage is not apparent (2). Although cheap and easily replaceable, these helmets are very difficult to recycle, as different types of materials are used, and are hard to separate at the end of life due to the usage glues/adhesives and other permanent joining methods, that not only make it very difficult to tear apart and prevent its recyclability.**

In the search for alternative, more sustainable materials that go in line with the United Nations 2030 Agenda for sustainable development, Expanded Cork (EC) was found to be a possible alternative to EPS, as a lightweight, relatively cheap material. EC is commonly found in the shape of boards for home insulation and decoration. Unlike other types of cork, EC is 100% natural and the only insulation material in the market to be carbon negative (3). It is manufactured into large blocks that are cut into sheets of the desired thickness. It was decided to take advantage of this available product and design a helmet consisting of a semi-rigid structure making a foldable helmet, meeting the principles commonly associated with micromobility. Besides, the desire for a helmet that occupies less space when not in use is not new. When bicycle helmets started appearing in the 20th century, they were comprised of a leather ring with a wool ring overhead. Forming a semi-rigid structure that allowed them to fold up, like a hat (4).

The cork structure of this helmet is composed of two side parts and a center band. These parts are composed of small polygons connected by a thin layer of cork, and are then covered by a stretchable fabric. Creating an elastic effect that will help in shaping the helmet to the user's head. At the end of life, the components can be separated. In the case of the cork, it can be used in other applications, where it can be recycled or processed to generate biomass for energy production (5).

Keywords— Helmet; Expanded Cork; Sustainability

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Development of a model for a freezer integrating phase change materials

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Abstract— **Residential buildings in Europe and the USA use 25%-37% of energy, with cooling appliances consuming a significant amount of power since they are connected to the grid 24 hours a day[1]. It is estimated that are 1.5 billion domestic refrigerators and freezers operating globally, which consume 450 kWh each annually, representing almost 4% of global electricity consumption[2].**

Cold-energy management has been a research topic in recent years involving thermal energy storage (TES) systems. These systems use a thermal storage tank to store excess cold energy and release it as needed. The main benefit of this approach is the ability to adjust operating conditions, such as rescheduling working hours, which significantly reduces energy consumption [3].

Due to their numerous benefits, phase change materials (PCMs) have gained significant attention recently [4]. These materials can store and release large amounts of latent heat over a specific temperature range when undergoing a phase transition, making them ideal for TES applications. Incorporating exothermic and endothermic phase transitions in TES systems can increase their efficiency. PCMs are also environmentally friendly and can store substantial thermal energy in a small volume, making them a desirable option for heating and cooling applications [5].

Various computational methods are employed in low-temperature TES systems to improve the performance of PCM-based systems. These methods aid in predicting the characteristics of PCMs, enhancing heat transfer properties, optimizing TES system design and operation, and conducting techno-economic analyses of TES systems, among other applications [6].

This study aimed to develop a computer model using TRNSYS 16 to evaluate the performance of a freezer that utilizes phase change materials. To accurately model the thermal behavior of the PCM, a new component was created using the heat capacity method. Additionally, Type 936 was improved to enable a more flexible analysis of variables. The results indicate that using PCMs in a freezer, with appropriate conditions and parameters, can lead to increased equipment autonomy and reduced energy consumption. Preliminary results indicate a significant increase of 38% in autonomy.

Keywords— Phase change materials; Refrigeration; Heat Storage; Energy Efficiency; Numerical modelling; TRNSYS.

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Transport solutions for storage and deliver in autonomous kitchen

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***Abstract*— The implementation of robots and sensors in industries is increasingly common. The evolution to industry 4.0 allows for real-time data collection and analysis, making industrial processes increasingly autonomous production, [1]. The market for autonomous kitchen is expanding. This work aims to develop an autonomous transport system for packaged meals to be integrated into a kitchen where meals are prepared, cooked and delivered to the customer without human intervention. There are many ways to automatically transport objects between two positions (conveyor belts, automatic guided vehicles (AGV's), robotic arms, just to name a few). Given the specifications of the project, namely the destination position of the object, which can vary in 3D space depending on the type of packaged food to be transported and the availability of the delivery spaces, a 3- axis linear system was selected.**

The gripper of the transport system was designed according to the variability of the shape of the packaging used for the meals. Different possibilities such as soft grippers, 2 fingers grippers, 3 fingers grippers, etc. were considered. The most promising solution, the soft grippers that allow picking up delicate items and/or irregular shapes [2], was not considered since the kitchen does not use compressed air.

The 3-finger gripper facilitates the process of picking up and dropping the object, which allows for better repeatability in positioning the object [3]. However, the 3-finger gripper solutions researched did not allow an easy adaptation for pick and place packages of different shapes and dimensions. Therefore, we opted for the use of a gripper with 2 parallel fingers, and it was customized considering the shapes and dimensions of the packages to be used and the maneuvering space to place the packages in the delivery spaces.

The whole system will be controlled by a programmable logic controller and will be integrated in the high-level control system of the autonomous kitchen.

Keywords*— *autonomous kitchen; mechanical project; pick-and-place; electric gripper; linear axis system;

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Development of an automated packaging system for an automated kitchen

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***Abstract* – Nowadays, the existence of robots working side by side with humans is a normal occurrence. Hospitality services, such as restaurants, are no different. These automated systems can do various tasks like helping in back-of-the-house chores such as slicing ingredients, grilling, and frying or front-of-the-house responsibilities like collecting plates, greeting customers, and serving [1]. When it comes to plating, there are little to no examples of fully automated plating and delivery systems. This project aims to develop a fully automated plating system integrated with an autonomous kitchen. This will alleviate furthermore the repetitive tasks required of human workers. The systems developed, at the moment, are intended to plate simple meals which require basic movements like pouring.**

A benchmarking study was made of systems with similar applications in the industry for dispensing, sealing, and transportation of goods. Some of the examples found include coffee cup dispensers, paint canning, and processed foods assembly lines [2] [3].

Subsequently, concepts of different assembly lines and systems to be implemented were compared so as to choose the most reliable solution to the project. The concept that was defined at this stage was similar to the ones observed in the industry [4]. A conveyor belt is used with the various dispensing and sealing units installed on top of it. First, a package is dispensed, then the conveyor advances to an open area where a robotic arm pours the meal into the package. Afterward, it is positioned below a lid dispenser, before it is pressed and sealed to serve. All these systems are controlled with a programmable logic controller and the precise positioning is monitored with the use of infrared lasers.

At the moment, the first prototypes have been manufactured and testing is ongoing. The main focus is testing the repeatability of the workflow required.

Keywords – autonomous kitchen; dispensing units; packaging; plating system; sealing; conveyor belt.

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Development of an Automated Solution for Spice Dispensig

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***Abstract*— Wish and Cook, a startup based in Portugal, has partnered with the University of Aveiro to initiate the Cook4Me project. The aim of this project is to revolutionize the restaurant market experience by providing a fully autonomous kitchen for customers to create personalized meals using an application, with a focus on healthy and generic recipes, as if they were cooking at home [1].**

The main objective of this work was to develop an automated system for spice dosing system, it presents the necessary phases for develop a functional prototype to be applied in the Cook4Me kitchen.

The work began by identifying the needs and challenges of the project [2]. The concept was developed ensuring precision in the system's actions and its integration into the kitchen were two major factors to be considered. A study of the current market was conducted, including the food industry and also for systems that use actions for small volumes of a specific element to find solutions for each action and create innovative solutions. The concept was developed by creating diagrams and sketches according to the possibilities that emerged. The concept selection was divided in two moments: selection of the order of actions and the solution to be used for each of the actions [2]. The concept was then projected in a 3D CAD software, with careful consideration of the mechanical structure details of the project [3].

In the final stage of the project, a physical prototype of the dispensing system was constructed to assess its dispensing capacity and its ability to interact with the other components in the kitchen. To automate and control the dispensing system, an Arduino microcontroller was employed, alongside several electrical components [4]. Additionally, communication between the dispensing system and the kitchen was established and tested using the MQTT protocol, which enabled a reliable and secure connection between the microcontroller and the MQTT broker [5].

As a startup project, there was a constant need for adaptation to the needs that arose since the Cook4Me project was not yet fully defined. Thus, there were several advances and setbacks to ensure that all systems could be incorporated into a fully interconnected kitchen. Finally, a solution was reached that met the needs and requirements created and was in line with the rest of the kitchen.

Keywords*— *Autonomous Kitchen, Dispensing System, Prototype, Arduino, MQTT.

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TOPIC

2) Technologies for the Wellbeing
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Development of a automatic washing system for an autonomous kitchen

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***Abstract*— One of the tasks to be performed in a kitchen is washing and drying the cooking containers. In an autonomous kitchen these tasks will have to be performed in a fully automatic way to guarantee continuity of the process.**

There are many commercially available products for washing and drying both in the home and in catering for a large scale. However, these equipment's are not fully automatic and rely on humans to at least load and unload the kitchen containers.

The aim of this work is to develop a fully automatic operating washing and drying system, which uses industrial machines already on the market for washing and drying and is capable of being loaded and unloaded by a robot arm in the autonomous kitchen.

The development of this system followed the product development architecture methodology. From the outset, maximum modularity and expandability were maintained as mandatory requirements to follow. A washing and drying solution was adopted on two different machines, adapted from existing products on the market, being fed by a continuous and expandable system for increased cadence in future developments. The system makes use of a roller chain with four cogged wheels, accessories and supports that make it compatible with loading and unloading using a robot arm. The transport system enables the washing and drying machines to be supplied with containers of different shapes and sizes (pots, pans, containers for ingredients and spices).

The rinsing temperatures, as well as the detergents used, ensure that hygiene requirements are met. Furthermore, the drying temperatures allow for a fast drying process enabling the system to have a high cadence.

This is a work in progress, currently being assembled for testing and later integrated into the autonomous kitchen system. By then the kitchen will have the capability to reuse the utensils to keep its operations going.

Keywords*— *Washing and drying; autonomous kitchen; automatic operation.

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INTELLIGENT SYSTEMS

MyEyes

Garnments Detection and Classification using Region based - CNNs

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Abstract— **Although technological developments in the last few years have been exciting, there are still many gaps when it comes to helping those who are blind. How we dress reflects the person we are in the world. Every day we face a dress code for work, going out to dinner, in a musical festival, among others. Something that for most of the population is a simple and stress-free task can be very hard for those who are blind. Previous work shows that for the blind community not knowing garment types, colors, and patterns is a demanding challenge [1]. Nowadays, there are some apps to assist the blind in planning what to wear and combining clothes despite not having been developed with them in mind [2]. When it comes to the detection of garments, we can find projects that detect the garment using Conditional Random Field [3], yet it shows some problems with clothes used on the same body part. Another project that can be found uses a deformable semantic locality-preserving network demonstrating good results regarding the corners of the pieces of clothing [4]. Focused on blind people we can find projects that identify the colors and patterns of clothes [5]. Additionally, MyEyes has previously undertaken efforts to assist blind individuals, including the development of combination systems [6-9]. However, until now, no previous endeavors have specifically targeted the automatic identification of characteristics in clothing items. Therefore, the project presented in this study makes a significant contribution to this field, enabling the automatic extraction of features for the identification of clothing items using artificial intelligence algorithms. This is achieved by extracting garments from images with varying backgrounds and cataloging them in a database to augment the effectiveness of the algorithms in identifying and extracting the clothes' characteristics [10]. The resulting dataset comprises polygonal segmentation for locating clothes in 1,120 images across eight garment categories (classes), including dresses, jackets, pants, polos, shirts, shoes, shorts, and t-shirts. By using Region Based Convolution Neural Networks (R-CNNs), it was possible to detect objects, including garments. To train and test the garment recognition network, we utilized the dataset developed in this study, which was split into training and validation images with ratios of 0.8 and 0.2, respectively. For the eight classes of garments detected, label results are above 77% regarding average precision for all categories. In the experiments performed we evaluated the influence of a different number of training iterations, data augmentation, and preprocessing, analyzing the impact on the results. To streamline and enable future research efforts, the collected data is stored in a centralized database.**

Keywords— Blind people; Garments recognition*; *Machine Learning; Object Detection.

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3) Intelligent Systems
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Evaluation of semantic reconstruction algorithms for damage detection and recognition in 3D models

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***Abstract* — The reconstruction and repair processes of metal parts through additive manufacturing have significant limitations in the scope of the process, as these are developed based on specific parts or damage, causing repair incompatibility with arbitrary parts and variable defects [1]. This limitation makes the implementation of these processes in the industry limited or unfeasible. Currently, several studies [1]–[5] have emerged that proposed methods to allow the automation of different steps in the metal parts repair process chain, namely in detecting and recognizing defects, reconstructing the nominal model of the part to be repaired, and in the generation of trajectories.**

This work presents a method that promotes automation in detecting different types of damages in 3D mesh models through a Python algorithm, which uses the Open3D library and is based on plane segmentation and the RANSAC (Random Sample Consensus) algorithm with DBSCAN (Density-Based Spatial Clustering of Applications with Noise) algorithm. The developed defect detection algorithm was tested through a damaged parts dataset, whose missing volume and geometry are known a priori, particularly with defects in the part surface, edges and corners. The presented method shows the procedure for damage detection and the validation test through the comparison between the detections and the ground truth data. Two evaluation metrics, the precision and recall values are presented to demonstrate the detection algorithm performance based on the plane segmentation and clustering parameters. The result of this work shows the accuracy of this method and its ability to integrate into automated repair systems through additive manufacturing.

The automatic detection of defects, as well as the characterization according to position and volume, allows for the definition of new automatic repair strategies.

Keywords*— *Automated repair systems; 3D model semantic reconstruction; Damage detection; Point cloud plane extraction; 3D point clustering;

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Development of a Vision System for Monitoring Cooking in an Autonomous Kitchen

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***Abstract*— With the rise of autonomous kitchens, there is a growing need for effective monitoring systems to ensure that food is prepared safely and to high-quality standards. In this study, we present a novel vision system designed to monitor cooking processes.**

Image processing systems have become essential across industries, improving efficiency, safety, and automation. Hardware is essential for image acquisition, processing, and analysis. Advancements in lighting, camera resolution, sensors, and processors have improved image quality and allowed us to process large amounts of data faster, enabling low-cost, compact systems such as the Raspberry Pi and Arduino [1]. In addition, preprocessing techniques have improved the quality of the images, making them easier to analyze for machine learning algorithms. These improvements have resulted in powerful and accurate machine vision systems used in healthcare, manufacturing, transportation, and other industries such as the food industry [2, 3, 4].

Using the Raspberry Pi with the Pi HQ camera and the OpenCV library for image pre-processing, we built a vision system for monitoring cooking in an autonomous kitchen. The system was designed to use the fewest number of cameras required for efficient monitoring, reducing costs as well as making installation simple. The cameras were operated with a linear motion along a linear guide controlled by an Arduino microcontroller. Pre-processing is performed on the picture retrieved from the vision system with the aim to prepare it for real-time tracking utilizing advanced machine learning techniques. We gathered data from a range of cooking settings and extracted the primary elements from pictures of cooking processes to validate the system's effectiveness.

Keywords*— *autonomous kitchen; food safety; vision system; machine learning; real-time monitoring.

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3) Intelligent Systems
   a. Identification systems.

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A container-based cloud-to-edge approach to support industry 4.0

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***Abstract*— The increasing complexity of industrial processes, and the necessity to adopt solutions to increase their efficiency and improve maintenance tasks lead to the adoption of monitoring sensors in most industrial assets. The sensor data data may be used to detect anomalies, estimate the remaining useful life of equipment, to identify root causes of some failures, among other functionalities. The fact that massive data are produced on the shop floor, leads to the necessity to adopt a suitable architecture to manage efficiently the data [1]. Traditional internet of things (IoT) approaches rely on the computational capacity of cloud computing to process and store all the incoming data flow, however it creates a burden on the network [2], and requires the cloud to have massive storage capacity.**

Currently, distributed solutions, exploiting the computational capacity of edge devices, are a trending topic in industry 4.0. Typically, these devices with less computational capabilities are used to perform some tasks such as data preprocessing, feature engineering, data filtering, and running predictive models. The adoption of edge computing solutions alleviates the burden on the cloud, but brings new challenges, such as the support for different edge devices, their remote management and update, the flexibility to integrate custom applications, and, the necessity to address all the privacy and security requirements of an industrial application [3].

In this work, we present a cloud-to-edge architecture based on the open-source OpenBalena project [4], which tackles the mentioned challenges arising from the adoption of edge computing. It consists of docker microservices running on the cloud, allowing the remote deployment of docker applications to fleets of edge devices, using secure socket layers (SSL) and transport layer security (TLS). An industrial use case on the injection mold industry is presented to illustrate the capabilities of the proposed approach.

Keywords*— *Data management; Edge computing; Distributed architecture, IoT.

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TOPIC

3) Intelligent Systems
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InovDesign

A self assessment tool for product design and development

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Abstract — **Product design and development (PD&D) are dynamic areas that require constant improvement and research. Nowadays, customers seek more specialized products, making it increasingly crucial to understand their desires and requirements when designing a product. Design for Excellence (DfX) is a general designation that integrates various design methodologies to optimize the PD&D process, although it can be challenging for engineers and designers to incorporate the wide variety of directives. In this work, a self-assessment tool, named InovDesign, was created to assist companies, engineers and designers by identifying the application and integration of different DfX directives on their PD&D process. This tool provides a quantitative (and graphical) representation of the current state of these processes within a company or department, acting as a basis for analysis and future planning. InovDesign grants companies and engineers the opportunity of not only self-assessing their current state of PD&D regarding the integration of multiple DfX directives, but also of improving their PD&D by highlighting which set of directives need to be improved or applied.**

InovDesign links which DfX set of directives should be applied at each PD&D stage and assesses the level of application of each directive through a Linkert scale. The tool accounts for five different stages/areas: Design for Concept Development (DCD); Design for the User (DUs); Design for Engineering (DE); Design for Use (DU) and Design for Sustainability and Circularity (DfSC). Moreover, it also assesses the company Organizational Process (OP).

Concerning product design, the DCD intends to generate preliminary ideas and concepts to assure that the envisaged product will fulfill its purpose and comprises the analysis of six topics: Failure Mode and Effect Analysis, Quality Function Deployment, Conjoint Analysis, Design Transfer, Rapid Tooling, Group Technology. Besides DCD, DUs is also an important stage of product design. It considers the interaction between product and user, by analyzing five distinct DfX approaches: Design for Ergonomics, Design for Aesthetics, Sensorial design, Design for a Sustainable Behavior, Intangible Design.

Manufacturing processes also play a key role in improving product quality, which is why DE is essential. This stage involves several techniques that can be applied in PD&D: Design for Reliability, Design for Operability, Design for Testability, Design for Manufacture, Design for Assembly, and Design for Disassembly.

Maintaining contact with the user throughout the entire life of the product is also crucial. The DU approach includes three main DfX techniques that must be considered by the industry: Design for Supportability, Design for Service, and Design for Maintainability. Concerning product life, sustainability and circularity are not just end-of-life concepts but should be incorporated throughout the product's entire life cycle. To assess this, InovDesign analyzes several DfX techniques: Design for the Environment, Design for Reuse, Design for Recycle, Design for Re-manufacture, Design from Recycling, Design for Update, and Circular Business models.

As previously mentioned, in addition to assessing the PD&D stages, InovDesign also assesses the company OP, by analyzing its management, engineering, marketing, and work conditions, particularly assessment of workspace ergonomics.

By using InovDesign, companies and PD&D professionals can assess their level of integration/application of the different DfX directives in all these strands and access guidelines to promote new ways to move forward on their PD&D. Future works intend to improve this tool by implementing artificial intelligence techniques, aiming to provide companies and PD&D professionals with a tool to aid in the development of new and improved products.

Keywords— Design for Excellence; Product design and development; Self-assessment tool.

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TOPIC

3) Intelligent Systems
   b. Digital transformation.

PMSP: An IoT Suite for Smart Industrial Monitoring

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***Abstract*— Big data and Internet of Things (IoT) devices are the cornerstones of smart manufacturing, yet sustainable solutions are seldom achieved, with over 80% of big data projects failing to reach production maturity [1]. Raw data is generated in large volumes from shop-floor devices and remains underutilized if proper processing mechanisms are not in place, overloading the industrial network and possibly hampering service quality [2]. The streaming nature of IoT data, characterized as a fast continuous flow of ordered elements, makes it incompatible with most traditional batch algorithms, leading to stricter memory and computational requirements. These factors open the field to innovations both on hardware and algorithmic fronts [3].**

This work introduces the Predictive Maintenance Smart Probe (PMSP) Suite for IoT-based devices built upon the robust STM32H7 microcontroller architecture and powered by a custom firmware aimed at solving complex data-driven industrial problems. PMSP enables the simultaneous use of both high- and low-level programming languages and provides an efficient embedded platform for running several well-known scientific packages. Moreover, it contains a comprehensive ensemble of sensing capabilities for industrial monitoring (e.g., temperature and air quality), and is fully integrated within a smart manufacturing platform. In line with the emerging paradigm of Industry 5.0, which places a larger emphasis on the human-technology synergy and focuses on notions such as the creation of workers' health protection protocols [4], a prototype version of the PSMP suite is tested using a real-world industrial use-case for the monitoring of worker conditions under harsh production environments. Furthermore, the streaming implementation of the novel Multiscale Impurity Complexity Analysis (MICA-S) algorithm, introduced in previous work [5], sees its first real-world application within a PMSP embedded device, and is used in quantifying data distribution variations of sensor readings.

Keywords*— *Internet of Things; Big Data; Smart Manufacturing; Industry 5.0

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TOPIC

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The Total Innovation Management and the Stage-Gates model

Contributions for the wellbeing and sustainable manufacturing solutions

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***Abstract*— This study explores a more pragmatic innovation management system (IMS), based on the Stage Gates Model developed by Cooper (1994), and on the philosophy of the five F, which can build solutions for the wellbeing and sustainable manufacturing. It required extensive bibliographic research, which was carried out in the scientific bases of Web of Science, Scopus, EBSCO and google scholar, and also used the snowball technique. The System is a wide platform, subdivided in four processes: opportunity identification; opportunity selection and prioritization stage; implementation and protection of opportunities; and process and metrics evaluation. Contributions from other authors from management were also included. The proposed model reflects the perspective of Total Innovation Management (TIM), and the latest research in innovation management models, which are dedicated to integrated models, systems integration, and business ecosystems.**

Keywords — Innovation; Innovation Management System; Organizational Innovation; Total Innovation Management; Wellbeing; Sustainable Manufacturing Solutions.

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Computation design as a tool for ideation

(Unblurring computational concepts)

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***Abstract* — One of the reoccurring problems in the design process is when the designer, architect or engineer becomes too focused on familiar solutions. This can happen when there is a heavy influence source of inspiration or prior knowledge becomes locked into certain ways of thinking. Design fixation is the name of this phenomenon and can affect the final product by not allowing the exploration of the full or larger range of possibilities [1].**

To solve this problem, the evolution of computational design has had a great role, allowing designers, architects and mechanical engineers the use of more tools and techniques to create and develop their solutions, moving beyond the common passive use of computational tools. In all these fields, professionals are using computer-based approaches to augment their spectrum of possibilities [2, 3], enabling the creation of optimized structures, the rapid and easy change of parameters, the sweeping of a vaster space of solutions, the creative exploration of shapes and more.

While all these contributions arising from various fields have been adding knowledge on the topic, their distinct origins have created a blurred landscape, in which interrelated terms such as parametric design, algorithmic design and generative design are frequently used indiscriminately to designate different things [4]. To further expand this problem, most of the projects that use computational techniques need not only one, but to combine these techniques in order to achieve their final goal. This non-critical approach, typical of emerging research process, with the combination of various computational concepts and their various uses, leads to misconceptions and creates constraints in learning and research.

One other aspect of this technology is that, even though it has the potential to help in ideation, it also implicates changes in the creative process, implying an understanding of the computational tools and techniques, as well as the design curation and evaluation. This implies a clear understanding of the algorithm, to locate and resolve possible errors, as well as to resolve the modeling itself [5].

Therefore, this work has two main objectives: to contribute with a consolidative model for computational design and to understand how computational tools relate to the creative process in product design. The study starts with an integrative literature review to clarify key concepts and redefine them in the context of computational processes. Concepts regarding the creative processes in design are explored and projects where concepts generation is assisted by computational tools are examined, to understand their mutual influences. Finally, a case study is conducted to develop a collection of products where 'designerly ways' of thinking are mediated by computational design to explore the potential and limitations of these tools in a real-world scenario.

Keywords — Computational design model; Parametric Design; Algorithmic Design; Generative Design; Design Thinking; Creative Process;

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Evaluation of the Injection Mold Performance Through the In-Situ Instrumentation and Data Acquisition System

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Abstract **– Injection molding is one of the most versatile and economic processes for the mass production of plastic components. During the molding cycle, molds are subjected to repeated thermo-mechanical stresses and deformations that can lead to thermo-mechanical fatigue and failure of the mold components due to fractures [1] [2]. Therefore, it is essential to quantify these deformations, high pressures and thermal loads to understand how to optimize the topology of the molds' components and avoid their over-sizing. This work aimed to develop and test the in-mold monitoring system to precisely quantify the fundamental mold variables, such as pressure, temperature, vibrations, strain, and displacement. An experimental injection mold was designed, made and fitted with: two pressure and temperature sensors (6190CA Kistler) inside the mold cavity; one strain sensor (SLB700A/06VA1 HBM) installed behind the cavity plate; one displacement sensor (U4-M-Cx Micro-Epsilon) and one accelerometer, both mounted at the mold's lateral side. The injection molding tests were carried out using Acrylonitrile butadiene styrene (ABS) plastic. The acquired data, shown in Figure 1, allowed to validate the developed monitoring system, as the recorded pressure and deformation values and profiles were typical for injection molding process. This observation is also valid for the data obtained from the vibration and displacement sensors.**

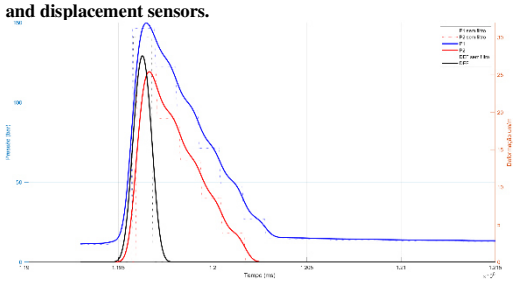

Figure 1 – Cavity pressures (P1 and P2) and deformation (DEF) profiles during the injection molding cycle.

Another important conclusion was drawn about the instant of the maximal deformation of the mold cavity plate, which, as seen from Figure 1, occurs at the beginning of the molding cycle packing stage, before the cavity pressure reaches its maximum, typically occurring during the packing stage. To confirm this observation, the packing pressure was increased two and three-fold. However, no statistically significant differences in the instant of the maximum cavity plate deformation and its values were observed. In addition, the recorded data may be applied to calibrate the material's model in the structural simulation of injection molds.

Keywords—Injection moulding, In-mould sensors, Mould monitoring; Data acquisition; Mould performance.

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Digital Health Factories

Supporting a Comprehensive Digital Transformation by combining Engineering and Health Sciences

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Abstract— **The lack of proper deployment and management of hospital technologies can be seen as one of the most significant barriers impeding the rapid expansion of hospital information systems development [1]. There several meaningful technologies that have difficulty in reaching the hospital setting, from data analytics, virtual reality to modeling. The utilization of both virtual reality (e.g. surgeries and management), modeling and simulation tools could provide knowledge to optimize hospital production processes and improve hospital services quality. The use innovative new digital approaches to designing and testing of new healthcare products (e.g. vaccines, sensors, diagnostic equipments) and hospital production processes (e.g., emergency greenways, digital care services and waiting list optimization) is an opportunity to improve access to care with more efficiency and efficacy. Progressive approaches utilizing the most progressive technologies of digitalization, rapid prototyping (clinical material 3D printing), virtual reality, modeling and simulation, require both time and investments. For instance, virtual reality can be used both as by the product development as by the design of production clinical processes, comfortable workplaces, improved production systems [2]. Together these approaches constitute the concept of Digital Factory [3]. We have been using (participative) design science research methodologies [4] to support an implementation approach for a Hospital Digital factory. We have been working with a hospital and health centers in the region of Lisbon implementing a set of digital systems that constitute an example of a digital health factory. The systems are the following: (1) Using modeling tools (FLEXIM) we have been modeling the optimization of emergency, surgery and diagnosis center services; (2) The development of the HAITOOL platform to help improve antibiotic prescription and reduce hospital infections [5]; (3) The participative development, supported by LEAN tools, of OSYRISH indoor location and gamification systems to improve nurses hand hygiene by providing real-time hand hygiene compliance [6]; and METHIS-Balance service, a digital platform to improve the distance treatment and monitoring of patients with balance disorder and risk of falls [7]. The combination of industrial and management engineering methodologies is creating a new culture and helping the translation of these methods to the context of wards and surgery rooms at the hospital level. Both the development of digitalization projects examples and the use of more sophisticated engineering tools are providing a better environment for the digital transformation of health care.**

Keywords— Digital factories; Digital Health; Digital Transformation; Design Science.

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Digital Transformation in the Water Sector: Present Situation, Future Prospects, Challenges and Opportunities

Transforming Water Management with Intelligent Systems: A Case Study on Operational Alerts and Notification

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***Abstract*— The water sector is undergoing a rapid Digital Transformation with the advent of new technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and big data analytics. These technologies are providing water companies with unprecedented opportunities to optimize operations and improve service delivery [1]. The objective is to offer a comprehensive view of Digital Transformation in the water industry. This overview will concentrate on the present state, potential prospects, obstacles, and possibilities for triumph. There is no question that the digital age has arrived, and a rapidly changing digital landscape is shifting government-owned infrastructure utility organizations toward Digital Transformation [2]. The transformation is inevitable as water and wastewater utilities are now facing new risks from increasing demand, water scarcity, water quality and water security [3]. The adoption of digital technologies will become necessary to provide improved, more reliable, secure, efficient, and cost-effective water and wastewater services [4]. Water companies that embrace Digital Transformation can unlock significant benefits and position themselves for success in an increasingly digital world. By adopting emerging technologies, water companies can overcome some of the biggest challenges facing the sector, including aging infrastructure, water scarcity, and climate change. Additionally, Digital Transformation can help water companies improve efficiency, reduce costs, and enhance the quality of service they provide to customers. Digitalization in the water sector, and their impacts on performance, greatly depend on digital maturity [5]. The identification of challenges that water companies encounter when implementing digital transformation strategies will be the starting point. Additionally, the discussion will cover the essential factors that contribute to the success of water companies that are interested in undertaking Digital Transformation strategies. Finally, a case study will be presented that showcases an intelligent alert and notification operational system. This system was implemented by a leading Portuguese water company and highlights the advantages of utilizing advanced analytics and machine learning to enhance real-time monitoring and response to crucial events. The case study is significant because it highlights the concrete benefits that can be derived from Digital Transformation in the water sector. In conclusion, the water sector is undergoing a significant Digital Transformation that presents both challenges and opportunities for water companies [6]. By adopting a strategic approach to Digital Transformation and leveraging emerging technologies, companies can overcome challenges and unlock significant benefits [7] and water companies are not exception. The case study presented provides a concrete example of the benefits of Digital Transformation in the water sector, highlighting the need for water companies to embrace emerging technologies to meet the evolving needs of customers and succeed in an increasingly digital world.**

***Keywords*— Digital Transformation, Digital Water, Digital Maturity, Digitalization, Digitation, Sustainability**

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Towards a new technologic world

The evolution industrial revolutions in Maintenance

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***Abstract*— The digital transformation created by the appearance of Industry 4.0 caused a change of paradigm into maintenance itself, which embraced it and appeared the concept of Maintenance 4.0 [1]. While on the other hand, the emergence of the most famous artificial intelligence, chat GPT, promises to change how all jobs are approached, including maintenance itself. This paper thoroughly contextualises Industry 4.0 and what is the simultaneous ascending Industry 5.0 [2], [3]. It is also be described Maintenance 4.0 and is presented some study cases about the application of this new concept, including the possible applications opened by chat GPT. It was concluded that Maintenance 4.0 is indeed the goal companies must pursue. However, Industry 4.0 can be seen as the explosive disruption of technology, hence the appearance of Industry 5.0, which emphasises human-centre, sustainable and resilient approaches. Maintenance 4.0, on the other hand, describes the application of technologies as a tool to improve mainly maintenance performance work. Virtual reality might exponentially improve workers learning, and when combined with additive manufacturing, a full-scale component could be produced, reducing the paperwork related to purchasing a new component. IoT, Cloud, Big Data structure and predictive and prescriptive algorithms could reduce most non-adding value work by appointing only the components that will fail. The chat GPT tool has also been proven to be adaptable to maintenance applications, brainstorming, clarification of concepts, writing guidance, chatbot, or knowledge manager. This AI also goes with the same philosophy of improving workers' efficiency, working as well as a tool of Maintenance 4.0.**

Keywords*— *Maintenance 4.0; Industry 4.0; chatGPT, Industry 5.0

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Machine Learning for the Geometric Optimization of Injection Moulds

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***Abstract* – During the injection molding process, the mould is subjected to an injection pressure that allows the polymer melt to flow and fill the cavities. Plastic components with deep cores will have a significant lateral pressure that can originate the appearance of defects, such as flash, on the plastic components.**

This work aims to analyze and optimize the lateral locking mechanism of large injection moulds using Machine Learning. A numerical model based on the Finite Element Method, was created and geometry and boundary conditions were parametrized, allowing to create a batch of 500 numerical simulations. The parameters analyzed were the dimensions a rectangular plastic vase (length, width, height), the injection pressure, and three geometric parameters that define the locking mechanism, as can be seen in Figure 1 (left). The output of the numerical simulations was the relative displacement between the core and cavity of the mould along the parting line. For a PE polymer, the maximum admissible opening is 0.03 mm, since a higher value will result in the appearance of flash (defect).

The created dataset was analyzed using a Neural Network (NN) composed of two hidden layers with 64 neurons each [1]. Figure 1 (right) shows the results obtained. As can be seen, the algorithm was capable of achieving a precision of 98.9%.

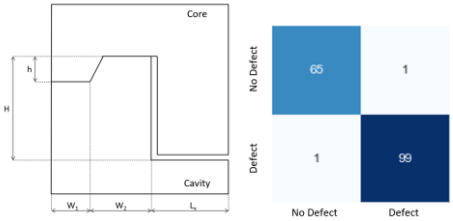

Figure 1 – (left) Schematic representation of the model and (right) results obtained by the Neural Network.

Afterwards, the Particle Swarm Optimization algorithm [2] was employed to optimize the geometry. The geometry of the plastic vase and the injection pressure are provided as input, and the algorithm outputs the geometric parameters of the injection mould, which minimize its volume (cost function). A penalty factor is considered in the cost function if a defect is detected. The results show that the PSO algorithm, in combination with the NN, can successfully optimize the geometry of the mold.

Table 1 – Results obtained for the optimization using PSO.

	w1 (mm)	w2 (mm)	h (mm)	Cost Function
Initial	**220**	**150**	**156**	**2057838**
Optimized	**31.7**	**71.3**	**16.1**	**2654.7**

The results obtained will allow for the development of a digital tool that the mould-making industry can use to avoid the over-sizing of the moulds, resulting in a reduction of the raw material (steel) and costs associated with the handling, transportation, and use of the injection mould.

Keywords— Injection Mould; Machine Learning; Neural Network; Finite Element Methods; Particle Swarm Optimization.

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A Machine Learning Approach to Calibrate Elastoplastic Constitutive Models for Sheet Metal Forming Simulations

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***Abstract*— Nowadays, numerical simulation tools are increasingly used for various engineering design applications, including the optimisation of sheet metal forming processes. The performance of these simulations depends on the precise identification of material constitutive parameters, etc. The classical strategy for parameter identification often resorts to a large amount of standardized mechanical tests, such that homogeneous strain and stress fields develop in the region of interest. However, such strategy cannot provide sufficiently precise and robust results, since sheet metal forming processes involve strongly non-homogeneous strain and stress fields.**

Inverse parameter identification strategies, such as Finite Element Model Updating (FEMU) and the Virtual Fields Method (VFM), make use of non-standardized mechanical tests allowing heterogeneous strain and stress fields [1, 2]. These methods have proven to be quite effective for linear and nonlinear models, but the process of these strategies has high complexity and computational cost. In this work, a different strategy is addressed, where a Machine Learning algorithm is used to identify parameters of nonlinear models using heterogeneous mechanical tests. First, the inverse ML model is trained from a database created through Finite Element software, Abaqus. In this software, the test specimen is modelled, and simulations are performed to be used as a data source. After establishing the database and the training of the inverse ML model, sensitivity studies are performed to understand the influence of the data set size and the mechanical test results on the predictive performance and the computational cost of the ML model.

Keywords*— *Material parameter identification; Machine learning; Sheet metal forming.

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Towards a personalized healthcare conversational agent using unsupervised learning

Leveraging Artificial intelligence combined with electronic health records

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***Abstract*— Patients' after cardiothoracic surgery rely on clinical appointments, therapeutics, modifiable risk factors, and psychological support to have a better recovery and enhance the effects of surgery [1]. Regular physical activity and a healthy diet positively affect most of the risk-modifiable factors for patients with cardiovascular disease, such as blood sugar reduction, weight, and blood pressure [2].**

Behavior change interventions have been used to follow the process of change and make interventions reproducible [3]. Conversational agents (CAs) have been harnessed to deliver such interventions given that they are a feasible and inexpensive way to provide tailored content [4]. Interventions and the content delivered should be tailored to the patient's needs [5].

To personalize the intervention, we focused on performing stratification of patients, based on clinical guidelines provided by health professionals, who underwent cardiothoracic surgery based on electronic health records collected over 10 years. Machine learning (ML) was applied to phonotype patients to understand what patients are needs after surgery.

The methodology used began with data exploration, handling missing data, data normalization, and feature selection. A model was selected given the premises for the present problem: (1) the groups are unknown, (2) the group to which each patient belongs is unknown, (3) a finite number of groups is required to decrease the complexity of the decisions made by the model, (4) the reasons for group assignment need to be known.

Unsupervised learning was used to tackle a well-defined problem which is the personalization of a conversational agent. K-modes, k-means, and k-prototypes clustering algorithms were used to stratify patients [6]. Models obtained were understood using explainable AI in order to fully comprehend their outcomes and what are the patient's needs given the cluster to which each patient is assigned [7].

Keywords— Cardiac Surgery; Behavior Change Intervention; Conversational Agents; Personalization; Machine Learning; Unsupervised Learning; Explainable AI

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Implicit constitutive modelling using RNNs and indirect training

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***Abstract* - Constitutive models mathematically encode the relationship between stress and strain for a given material. Under plasticity this relationship is highly non-linear and often depends on the loading history. Accurately modelling this path-dependency is critical for predicting the material response under different loading conditions. Artificial Neural Networks (ANNs) can implicitly learn constitutive relations directly from data, without assuming a mathematical formulation. Particularly, Recurrent Neural Networks (RNNs) can model temporal data by maintaining an internal memory of past inputs. As such, RNNs have been shown to be effective in capturing the effects of loading history for materials that exhibit path-dependent behaviour.**

Implicit constitutive modelling approaches in the literature rely on training ANNs with paired data, usually stress-strain, from numerically generated datasets. Nevertheless, in a real experiment, variables such as stresses are not measurable and the training should be carried out indirectly, using experimentally measurable variables only.

Although, in theory, any ANN could be able to learn the constitutive behaviour of a material, given enough data, it usually works as a black-box model, as its structure is not easily interpretable and there is no guarantee that its predictions are usable, as they can violate fundamental laws of mechanics and thermodynamics. Thus, it is necessary to enforce physics-based constraints when using ANNs for implicit constitutive modelling. Physics-based constraints act as a regularization agent for ANNs, reducing the space of admissible solutions and allowing the network to learn with smaller datasets, as it already does not have to learn those relationships from data. These constraints can be enforced using custom ANN architectures, model constraints (e.g., weight constraints) or penalty/regularization terms.

In the present work, an RNN-based material model is trained using a novel indirect approach, where the local and global equilibrium conditions are ensured employing the Virtual Fields Method (VFM). Physical constraints are analysed and applied during the training process.

Keywords* - *constitutive model, elastoplasticity, recurrent neural networks, indirect training, constrained optimization

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