TEchMA2021

4th International Conference on Technologies for the Wellbeing and Sustainable Manufacturing Solutions

Aveiro, 21st of January 2021

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Aveiro January 21st 2021
The Director,
António Bastos Pereira

TEchMA2021

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Contents

Program

Opening Session	**Tema Director António Bastos and DEM Director Robertt Valente**		9:30
Sustainable Manufacturing Solutions			
Session I (João Oliveira)			9:40
Manufacturing Processes & Simulation	Recommendation engine and uncertainty techniques for the efficient calibration and selection of thermomechanical constitutive models: modernity and importance of the thematic	Mariana Conde	
	Design of novel heterogeneous thermomechanical tests using topology-based optimization methodologies: motivation and prominence	Mafalda Gonçalves	
	Multi-objective optimization of Ti6Al4V machining using numerical simulation with FEM	Sílvia Carvalho	
	Influence of injection molding processing conditions on the dimensional stability and defects' prevalence in ABS chrome plated parts	Tatiana Zhiltsova	
	4D Printing: Development of fused filament fabrication structures with the ability to shape-shift	Dina Gamelas	
	Topology optimization of thermoelastic structural problems using a new bidirectional algorithm	Mafalda Gonçalves	
Coffee Break			10:40
Session II (Margarida Coelho)			11:00
	Development of a Framework for an Automated Mechanical Testing	Diego S. Nunes	
	Digital twin development in metal forming calibration aided by digital image correlation and artificial intelligence	João Diogo Henriques	
Manufacturing for Circular Economy	Simplified evaluation model for hot water storage tanks: Evaluation of PCM's integration and solar colectors	Diana Pinho	
	Crashworthiness Design Optimization of Lightweight 3D Printed Structures	André Lourenço	
Technologies for the Wellbeing			
Session III (Margarida Coelho)			11:50
Innovative Technologies for Smart Cities	Development of a new classification system for Mobility as a Service platforms	João Teixeira	
	Real driving emissions in passenger cars: Developing new predicting models based on engine parameters and driving volatility indicators	Paulo Fernandes	
	An Integrated Assessment of Road Traffic Noise and Pollutants Critical Hotspots through Advanced Models	Antonio Pascale	
Lunch Break			12:30

Session IV (Gil Andrade-Campos)			14:00
Innovative Technologies for Smart Cities	Adaptive Control Strategy for Efficient Conversion of Photovoltaic Energy to Mechanical Work: An Innovative Scheme for Maximum Power Point Tracking and Optimal Load Modulation	Luís S. Rodrigues	
	Evaluation of Impacts on Intercity Corridors for Efficient and Sustainable Mobility: Innovative Ways to Address Corridors Pricing	Carlos Sampaio	
	Carpooling as a Strategy to Urban Mobility During Public Health Threats: A Case Study in a University Campus	Ricardo Tomás	
	Household Thermal Energy Storage in the Context of Smart Grids: Viability and Potential Impact of Small Residential Consumers in Demand-Side Load Balancing With The Use of Phase-Change Materials	Luís S. Rodrigues	
	Micro-analysis of a diesel vehicle driving volatility and impacts on emissions for intercity corridors	Elisabete Ferreira	
	A Life Cycle Assessment of Shared, Automated and Electric Vehicles: Optimization of a fleet mobility system applied at a regional case study	Mariana Vilaça	
	Decision support system for accessing costs and risks of connected and autonomous vehicles as mobility service in urban contexts	Mónica Rodrigues	
Multiscale Technologies and Devices for Medicine, Environment & Energy	Development of an adsorption heat pump prototype for domestic water heating	João M.S. Dias	
	Development of a Passive Orthosis for Reducing the Load at Hip Joint	Tiago Rodrigues	
Coffee Break			15:30
Session V (Gil Gonçalves)			15:45
Multiscale Technologies and Devices for Medicine, Environment & Energy	High affinity of 3D spongin scaffold towards Hg (II) in real waters	Eddy Domingues	
	3D reduced graphene oxide-based scaffolds with fibrous-porous architectures for neural tissue engineering applications	André F. Girão	
	Automated manufacture of anisotropic electrospun scaffolds towards articular cartilage repair	Ângela Semitela	
	Experimental and numerical investigation: On the characterization of a transcritical CO_2 variable-speed scroll compressor	Francisco Lamas	
	Performance evaluation of different control strategies for tankless gas water heaters	Ismael Ehtiwesh	
	3D anisotropic scaffolds for spinal cord regeneration	Joana P.M. Sousa	
	Embedded implementation of predictive control strategies for gas-fired instantaneous water heaters	André Quintã	
	New opportunities for 3D Printing at TEMA: Wanna know more?	Nathalie Barroca	
	Engineering self-regulating construct-bioreactor to model the dynamic microenvironments of realistic tumors	João F. Gil	
	Platooning optimization with mixed vehicle arrangements based on performance and environmental indicators	Micael Rebelo	
Closing Session			17:30

SUSTAINABLE MANUFACTURING SOLUTIONS

Recommendation engine and uncertainty techniques for the efficient calibration and selection of thermomechanical constitutive models

M. Conde [(a), (*)], A. Andrade-Campos [(b), (*)]
(*) - Department of Mechanical Engineering, Centre for Mechanical Technology and Automation (TEMA), University of Aveiro
(*) - Aveiro, Portugal
(a) – marianaconde@ua.pt; (b) – gilac@ua.pt

***Abstract* — Nowadays, digitalisation and virtualisation are the keys for companies' success and competitiveness. Thus, numerical simulation tools are essential for engineering analysis and development. The success of a simulated material behaviour prediction depends on the chosen complex constitutive model and the correctness of its parameter identification. These days, it is used several classical mechanical tests to identify the model's parameters. However, this method is non-robust** [1]**, time, and cost consuming. Non-homogeneous mechanical tests provide richer mechanical information, requiring fewer experiments while offering more complex stress states, that better represent reality** [1], [2]**. Its trustworthiness for the material parameter identification, numerical prediction, and simulation of materials was been proved in** [1]–[4]**. Besides, a large number of constitutive models have been developed** [5], [6]**, implemented in the FEA simulations, and validated** [6]**, in the last decades. But its choice is a hard task, even for experts. The majority of works analyse and compare different models for specific applications** [7] **and do not find a suitable strategy for its automatic selection. It is proposed the development of key performance indicators (KPI's) for the accurate selection of constitutive models as a recommendation engine. This feature will help in the calibrated constitutive model decision making, ensuring suitable material reproduction. Besides, a test involving non-homogenous strain fields and complex strain paths will be designed to reduce the number of experimental tests. These solutions are expected to increase the reliability in the FEA simulations, reduce the development lead-time of engineering metal parts, reduce the number of experimental tests required for the mechanical behaviour characterisation and reduce time, waste, and costs on the overall development process. Hence, these innovative solutions will increase companies' productivity and efficiency.**

Keywords — mechanical constitutive models; mechanical test design; uncertainty analysis; key performance indicators (KPI); recommendation engine.

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1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

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Design of novel heterogeneous thermomechanical tests using topology-based optimization methodologies: motivation and prominence

M. Gonçalves [(a)], A. Andrade-Campos [(a)]

(a) – Department of Mechanical Engineering, Centre for Mechanical Technology & Automation, University of Aveiro, 3810-193 Aveiro, Portugal.

(a) – mafalda.goncalves@ua.pt

***Abstract* — Nowadays, the development and design of new mechanical parts are performed using virtual manufacturing tools. For this purpose, numerical simulation software uses complex material constitutive models to reproduce real material behavior. However, the reliability of the simulation's results is conditioned by the accuracy of the input data. The calibration of material models depends on a proper material characterization, which turns to be expensive due to the required large number of mechanical tests. Moreover, the homogenous stress-strain fields generated by standard tests do not reflect the ones which occur in the most common forming operations. Therefore, there is a need to design a new heterogeneous test that provides the necessary amount of information by inducing heterogeneous strain states in the specimen and, consequently, providing a cost-efficient and precise calibration of constitutive models. Several works have already addressed this topic by optimizing the specimen's geometry. However, used on its own, shape optimization consists of a limited procedure [1]. An alternative approach based on topology optimization is suggested by a few works to overcome this limitation [2,3]. Therefore, this Ph.D. thesis proposes the design of an innovative thermomechanical test using topology-based optimization methodologies. The evaluation of the richness of stress and strain fields on the specimen will be carried out by mechanical indicators, applied as a cost function. Alongside, synthetic images will also be used in the design process to virtualize the measurement phenomena. The numerical results will be compared to the ones achieved experimentally. The induced heterogeneous strain states will be measured through full-field experimental techniques such as Digital Image Correlation (DIC) [4]. The outcomes of this work will enable the accurate calibration of thermoelastoplastic models, reducing the development lead-time of new parts and the waste associated with the classical mechanical tests. Finally, virtual manufacturing will be established as a more reliable option for the future of metal material testing and design. Besides the presentation of the general framework of the previously described Ph.D. project, a bibliographic review will be presented as well as the relevance of this work.**

Keywords — Heterogeneous thermomechanical test; Topology optimization; Specimen design.

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   a. Manufacturing Processes & Simulation

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Topology optimization of thermoelastic structural problems using a new bidirectional algorithm

M. Gonçalves [(a)], João Dias-de-Oliveira [(a)], R.A.F. Valente [(a)]

(a) - Department of Mechanical Engineering, Centre for Mechanical Technology & Automation, University of Aveiro, 3810-193 Aveiro, Portugal.

(a) – mafalda.goncalves@ua.pt

***Abstract* — Nowadays, Topology Optimization (TO) has been frequently used for the development and design of several engineering parts, providing lightweight and high-performance structures. However, the topological design of structures subjected to thermal gradients is not straightforward to solve. Caused by thermal expansion, thermomechanical loads, which are design-dependent, play an important role in structural design, posing several extra challenges to topology optimization. This work focuses on design-dependent thermoelastic stress loads by analyzing their impact on the optimization of a structure's material layout. Numerical examples are presented and analyzed by the classical approach to TO problems. The obtained results address the concerns pointed out by several authors related to the application of this approach to thermoelastic design problems [1-4]. Thermomechanical loads change during the optimization process, modifying the sensitivity analysis and leading to a non-monotonous objective-function. As a result, different instabilities appear in the optimization process and, consequently, in the obtained topologies, such as checkerboard problems, intermediate densities, and convergence limitations. In order to overcome these issues, the present work proposes an alternative procedure based on an evolutionary algorithm. A new approach to the Bi-directional Evolutionary Structural Optimization (BESO) [5] method is suggested. Two different schemes, hard- and soft-kill, are evaluated alongside a modified sensitivity number that is proposed to account for the thermoelastic stress loads on the optimization process. Finally, the obtained numerical results from the updated BESO method are analyzed and compared to the ones coming from the classical approach.**

Keywords— Topology optimization, Design-dependent loads, Thermoelasticity.

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Influence of injection molding processing conditions on the dimensional stability and defects' prevalence in ABS chrome plated parts

T. V. Zhiltsova1 [(a)], M. S. A. Oliveira [(a)], L. Nascimento [(b)],
(a) - TEMA – Centre for Mechanical Engineering and Automation, Mechanical Engineering Department, University of Aveiro
(b) OLI-Sistemas Sanitários, S.A.
(a) Aveiro, Portugal; (b) – Aveiro, Portugal
(a) – tvzhiltsova@ua.pt

***Abstract* — Acrylonitrile–butadiene–styrene (ABS) is an engineering plastic widely used in different applications. It offers high impact resistance, good stiffness, high dimensional stability at elevated temperatures and superior processing [1]. However, it is vulnerable to the environmental conditions and prone to water absorption, posing a challenge during its application in sanitary equipment. Metallic properties attained by electroplating on ABS surface eliminate the water uptake while improving the strength, durability, and thermal resistance [2]. The final quality of metallic layer adhesion to polymer substrate is affected by a number of factors such as: etching efficiency of chromic or sulfuric acid for dissolution of polybutene rubber particles at the surface for creation of strong interlocking with the metal deposition, quality of plastic materials, mold design, part design and the injection molding processing conditions [3]. Deficient processing may result in plating defects unacceptable for visible and decorative ABS parts, but may also compromise their dimensional stability [4]. Processing conditions must be tailored for the molded part specific design aiming to achieve the best possible quality. However, there does not exist a perfect set of the processing condition which address every quality criterion equally and hence some compromises are unavoidable. This is especially critical in case of family molds where mold design issues may aggravate the molded parts quality.**

In view of the above, the work here presented highlights a systematic approach carried out to to identify the origin of electroplated defects in the lid and buttons of a toilet flushing system action set, related to the injection molding processing conditions. Among these defects, spots with poor adhesion and warpage in the lid were the ones most frequently identified and reported. The approach undertaken involves, firstly, a diagnosis process numerical simulation for proper identification of the above defects probable causes. The results revealed several problems which might affect the molded parts quality such as: very high clamp force, non-uniform shrinkage between the cavity and core sides and along the length of the parts, warpage due to non-uniform cooling and unbalanced filling patterns between the cavities. The latter being a common occurrence in family molds, aggravated, in this particulate case, by the hybrid feeding system containing both cold and hot runners rendering balance even more challenging. To address these issues, the injection velocity was increased and linearly profiled to maintain a constant flow front velocity in the mold, while the packing pressure were decreased and profiled to minimize overpacking and shrinkage gradient especially critical around the gates, being one the consequences of the unbalanced filling. Unbalanced cooling, manifesting itself as in-mold residual stress and warpage in the principal plane direction, was corrected by equalizing the cooling temperature at the cavity and core sides of the mold. These corrective actions were implemented numerically and experimentally, in both cases indicating minimization of warpage in the principal plane direction which led to a decrease of the ABS electroplated lids rejection rate from 17.8% to 7.1%.

Keywords— Residual stress; Molding processing conditions; ABS; Chrome plating; Family mold.

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1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

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4D Printing

Development of fused filament fabrication structures with the ability to shape-shift

Dina Gamelas, Mylene S. Cadete. Tiago Gomes, Victor Neto
Centre for Mechanical Technology and Automation (TEMA), Department of Mechanical Engineering, University of Aveiro, Portugal
dina.gamelas@ua.pt, mylene@ua.pt, tiago.emanuel.gomes@ua.pt, vneto@ua.pt

***Abstract* — Fused Filament Fabrication (FFF) of 4D objects appears as a variant of additive manufacturing. The name 4D refers to the temporal component since the printed object undergoes a shape change when subjected to a stimulus, in this case an increase in temperature.**

This technology, still in development [1,2], has several advantages such as the reduction of the time of manufacture and the waste of raw material since many of the 4D objects obtained are based on flat patterns of solids that are later transformed into three-dimensional objects. Compared to the 3D printing of the intended final object it becomes obvious that the planification presents a simpler printing path and does not require the printing of supports. Another advantage presents itself in the transportation aspect since the simple printed geometry can be activated in the place of use.

Some of the aspects explored in this study are the shape memory effect, the formation of internal stress as well as the printing parameters that most affect its storage and lastly the printing strategies that best allow the control of the desired deformation effect.

Based on this, the design of a 4D object to be obtained by FFF is further explored. Figure 1 shows the conceptual model of a chair before and after being activated. This result is purely conceptual since the change of scale of the object is not considered neither is it planned to endure the work stress of a real size chair.

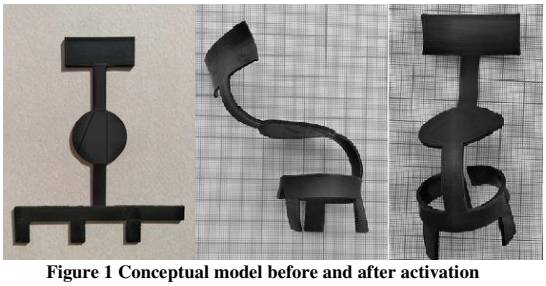

Figure 1 Conceptual model before and after activation

Keywords* — *4D printing; 3D printing; FFF; shape memory effect.

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Multi-objective optimization of Ti6Al4V machining using numerical simulation with FEM

Sílvia Carvalho, Ana Horovistiz, J. Paulo Davim
Center for mechanical technology and automation (TEMA)
Aveiro, Portugal
sdrc@ua.pt; Horovistiz@ua.pt; pdavim@ua.pt

Abstract **— Defining optimal cutting conditions, as well as controlling the machining process, are two tasks of great importance when machining difficult-to-cut materials such as Ti6Al4V. This alloy is used in high-value applications for the aerospace, biomedical and automotive industries due to its excellent combination of properties, such as high strength-to-weight ratio and excellent corrosion resistance. While manufacturing a component with these features is very appealing from the application point-of-view, other aspects of Ti6Al4V alloy, namely low thermal conductivity, severe work hardening during deformation and the capability of maintaining strength at high temperature, contribute to reducing the machinability of this material. To tackle this challenge, the solution may be controlling the machining process conditions, namely the cutting parameters and the cooling and lubrification methodologies. In this scope, machining simulation with FEM can be a useful engineering tool to understand the influence of the cutting conditions into the behaviour of the workpiece material, cutting tools, and metal chip** [1]**. This work reports on a methodology, that can be seen in *Figure 1* for machining process optimization. The work main goal was to understand through 2D simulations and Grey relation analysis optimization algorithm (GRA), which cutting settings should be reproduced experimentally to fulfil the multi-objective function. The GRA algorithm was applied to the data obtained by machining simulations, each output was maximized or minimized, considering the machining process aspects, for example, improving productivity, reducing residual stress, among others. Afterwards, the algorithm application comprises the creation of a single function which is a contribution of each individual response obtained in the previous step.**

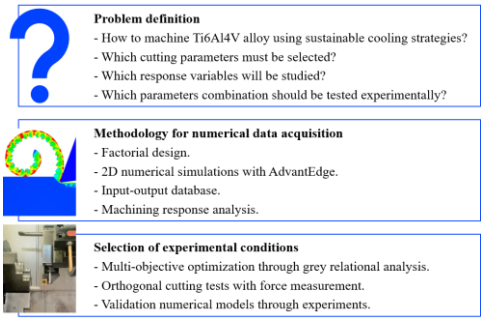

Figure 1. The methodology for machining process optimization.

In this stage of applying the algorithm, each simulated condition will have a single value associated with it, which will be used to rank all the simulated conditions and select the best settings to perform the experiments. GRA is a well-established technique for multi-objective optimization and the algorithm implementation can be consulted in detail [2], [3]**. In this work, several lubrification and cooling environments were simulated, since one of the research objectives was to understand if it is viable to use more sustainable cooling and lubrification approaches, such as minimum quantity lubrication and dry machining instead of flooded cooling to machine Ti6Al4V alloy, without compromising the aspects of the machining response, such as the workpiece residual stress, the chip compression ratio, the cutting forces, power and temperature obtained numerically, the material removal rate. The cutting conditions obtained after applying the GRA algorithm into the numerical data were then reproduced experimentally and compared with the simulation results.**

Keywords — FEM, multi-objective optimization; Grey relation analysis (GRA); Ti6Al4V; AdvantEdge

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   a. Manufacturing Processes & Simulation

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Development of a Framework for an Automated Mechanical Testing

Automatic specimen tray detection and handling procedure using a robotic manipulator.

D. S. Nunes [(a)], A. G. Andrade-Campos [(b)] , and M. R. Oliveira [(c)]
(a), (b), and (c) - Dept. of Mechanical Engineering; University of Aveiro.
(a), (b), and (c) - Aveiro, Portugal.
(a) – diegonunes@ua.pt, (b) – gilac@ua.pt, and (c) – mriem@ua.pt

***Abstract* — Nowadays, predict or characterize material's behaviour are arduous tasks which involve performing repetitive tests in material testing. When executed manually, they result in inaccurate data, due to the repeatability of the process. However, these handling specimen tasks could be performed automatically using traditional robotic manipulators, and creating systems based on automatic mechanical testing [1, 2]. Consequently, the precision of the testing results can increase, as well as the automatism of the processes and the test's throughput.**

Some commercial products are already available on the market, but these options are offered as entire closed-source solutions (hardware and software) and cannot adapt themselves to existing equipment or retrofitted systems.

In this work, it is created a communication infrastructure between the equipment to be included in the automatic system designed [3]. The whole process is managing the interface communication between devices and, consequently, composing the automatic material testing routine. This requires implementing several changes in the testing machine selected aiming to increase its degree of automation and, consequently, allow further integration in the fully automatic testing procedure. Additionally, a visual perception system is created using a specimen tray randomly positioned on a workspace, which includes a camera and robotic manipulator that is automatically operating the traditional specimen handling of testing (picking task). Here, a visual board reference (ChArUco board contained in the specimen tray) is detected by a machine vision procedure and the final picking coordinates of each specimen within the tray is obtained, in the manipulator's coordinate system format (through the relation of multiple geometric transformations). The calibration methods are accomplished using ROS framework and the final system achieved operates in automatic mode, handling specimens from the tray prototype (designed for this work) to a fixed position previously taught to the manipulator, which represents the exact feeding position on machine tests [4].

In the end, the results obtained allow the validation of the procedure created and its potential to be included in fully automated material testing systems to be designed in the future.

Keywords* — *Specimen handling; Automation; Material Testing; Robotic Manipulator; Tray Detection; Machine Vision; ChArUco board.

ACKNOWLEDGEMENTS

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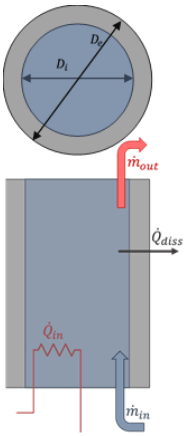
Simplified evaluation model for hot water storage tanks

Evaluation of PCM's integration and solar collectors

Diana Pinho [(a)(*)], Luís Costeira [(a)], Rafaela Reis [(a)], Ricardo Martins [(a)], Fernando Neto [(a,b)]
[(a)]*Mechanical Engineering Department*
[(b)]*TEMA*
University of Aveiro, Portugal
[(*)] dianapinho@ua.pt

***Abstract* — A simple model is proposed to preview the implications of using PCM's (Phase Change Materials) as storage media on a domestic water storage tank, using solar collectors as energy's source.**

An initial simplified transient model was developed for a simple hot water storage tank. This model is based on conservation principles (mass and energy) and resorts to low computational requirements, using just the Excel tool. This approach is used to predict the water's temperature throughout the day, the state of the electrical resistance (on/off), the electrical energy consumption and its cost. The model allows the user to make parametrical studies to evaluate the relevance of variables such as the setpoints temperatures, electrical power, type of insulation, water usage profiles, etc.



The benefits of this approach are mainly the small-time simulation and the low computational costs, usually required by most of alternative models [1]. This model provides a simple tool for researchers and engineers to simulate the behavior of a hot water storage tank.

The initial model was then enriched by adding new features as supplementary storage media (PCM) and solar input. Despite the fact that the model does not consider the temperature stratification in the tank [2], the obtained results seem to be truly promising according to the results of the ongoing validation procedure.

The parametric analysis conducted so far showed the importance of using storage media and the contributions of the solar component.

Keywords — hot water storage tank; modeling; computational cost; PCM; solar energy.

ACKNOWLEGEMENTS

This work is supported by the projects: UID/EMS/00481/2019-FCT - FCT - Fundação para a Ciencia e a Tecnologia; and CENTRO-01-0145-FEDER-022083 - Centro Portugal Regional Operational Program (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund.

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Digital twin development in metal forming: calibration aided by digital image correlation and artificial intelligence

J. Diogo Henriques [(a)(*)], J. Xavier [(b)], A. Andrade-Campos [(a)]

(a) Department of Mechanical Engineering, Centre for Mechanical Technology and Automation, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

(b) Department of Mechanical and Industrial Engineering, UNIDEMI – Research & Development Unit for Mechanical and Industrial Engineering, 2928-516 Caparica Portugal

[(*)] joaodiogofh@ua.pt

***Abstract* — The automotive industry benefits from a digital-twin paradigm on metal forming processes to increase efficiency and reduce the delivery-time of parts. The concept of digital twin can date back to Grieves's in 2003 [1]. However, at that time the concept of digital twin was not mature enough due to technology limitations. These virtual products will represent a replica of their physical counterpart, to deliver critical information of the closed loop product lifecycle. This approach should yield innovative solutions, increase the quality of the delivered products, and reduce costs [2].**

In this communication, a Ph.D. project is presented. This Ph.D. work aims to design a metal forming digital twin through: (i) the calibration of the constitutive models using advance VFM techniques; (ii) the approximation of the digital/simulation and experimental worlds via synthetic images construction; (iii) the development of an enhancer/corrector for the existing well-known models using artificial intelligence. This corrector module, using machine learning (ML) techniques, modifies the stiffness of the analytical material models formulation, providing flexibility to the hybrid module leading to an even better calibration and reproduction of the material behavior and (iv) the experimental validation using heterogeneous kinematic full-field measurements. The Arcan experimental apparatus will be used to calibrate an anisotropic elastoplastic model to an aluminium alloy and a DP-steel. The experimental data will be used to train the ML-corrector.

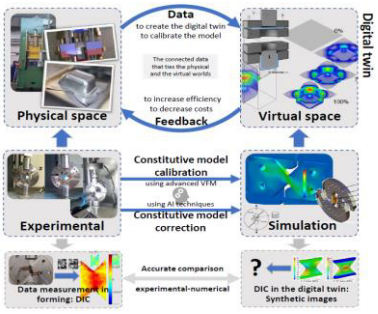

Figure 1 – Graphical abstract of the Ph.D. workplan proposed.

Hybrid models, assembling analytical and ML models were previously suggested [3], although all the effort of calibration is put in the non-analytical part. However, for obtaining a digital twin, all calibration and accuracy is needed.

Keywords — Digital twin; Consitutive models; Metal forming; Virtual fields method; Machine learning.

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Crashworthiness Design Optimization of Lightweight 3D Printed Structures

André Lourenço [(a)], Fábio A.O. Fernandes [(a)], João F. Caseiro [(b)]

(a) -TEMA, DEM., Universidade de Aveiro; (b) – CENTIMFE - Centro Tecnológico da Indústria de Moldes, Ferramentas Especiais e Plásticos

(a) Aveiro, Portugal; (b) – Marinha Grande, Portugal

(a) – aslourenco@ua.pt; fabiofernandes@ua.pt

***Abstract* — Structures responsible for impact absorption are constantly present in our daily lives. For example, they are used in the automotive sector within structures capable of minimizing propagation of the damage to the vehicle itself during a collision and to reduce the energy transmitted into the vehicle passenger compartment. Other applications for such structures are related with armour and personal protective equipment such as helmets and back protectors.**

The design of these structures is challenging and there is the need of optimising them based on specific requirements of each application. The objective of the current work is to obtain a lightweight structure and, at the same time, have a good energy absorption capacity.

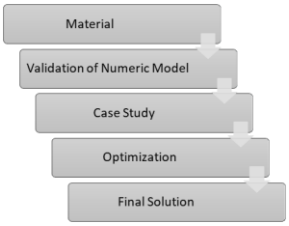
In this work, the energy absorption capacity of structures manufactured using additive manufacturing was studied, based on polyamide parts manufactured by selective laser sintering (SLS) [1-2]. This technology allows for the manufacturing of complex geometries which is not possible by traditional processes such as milling.

For analysis of the behaviour of the structures, the Finite Element Method (FEM) was adopted with the objective of validating the material modeland its mechanical behaviour, as well as the energy absorption capacity of the structures. In order to achieve such goals, a constitutive strategy based on damage models was adopted. The case study is an impact attenuator for a Formula Student, Europe's most established educational engineering competition. The structure was optimized using a DoE and response surface methodology (RSM) to obtain the parameters that define the final structure.

Keywords* — *Additive Manufacturing; Polyamide; Finite Element Analysis; Light Structures; Impact; Energy Absorption; Optimization, RSM.

Example of impact attenuator.

Methodology Diagram



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TECHNOLOGIES FOR THE WELL-BEING

Development of an adsorption heat pump prototype for domestic water heating

João M.S. Dias, Vítor A.F. Costa
TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro
Aveiro, Portugal
joaomdias@ua.pt; v.costa@ua.pt

***Abstract*— Nowadays, the need for comfort of the worldwide population is strongly increasing as humankind develops faster than ever. Providing domestic hot water and space heating for everybody is a demanding task that can have harmful environmental impact. Almost 80% of the total energy consumption in the residential sector is used for space and water heating. Thus, solutions must be found to prevent causing irreversible damages to the environment.**

Currently, the most competitive heating technologies that meet the market requirements are vapor compression heat pumps (VCHP). Unfortunately, this technology runs on electricity, which is still mostly obtained from non-renewable energy sources like coal, oil, or natural gas, uses harmful fluorocarbon refrigerants with global warming potential and ozone depletion potential and generates noise and vibration. One of the possible alternatives to VCHPs are the thermally driven adsorption heat pumps (AHP), use natural refrigerants such as water or ammonia and do not produce noise and vibration, making them suitable for domestic applications.

Several developments have been recently made in AHP technology [1]**. However, most experimental studies rely on small scale prototypes, with a few grams of adsorbent material, which results on very low heating power. Developing and testing real scale prototypes is not straightforward since it requires vacuum technology, which is one of the major hindrances of AHPs** [2]**.**

This work reports the construction of an AHP system prototype, which is expected to achieve a heating power of 5 kW accordingly to theoretical models. The developed AHP system is suitable for domestic water heating and consists mainly of the following components: silica gel-water adsorber, evaporator, condenser, gas burner, domestic water reservoir, expansion valve, vacuum valves, centrifugal pump and control valves. The adsorber contains 16 kg of granular silica gel packed around 50 metal tubes with 1 m length. The metal tubes are enclosed in a cylindrical vacuum chamber which is alternatively connected to the evaporator and to the condenser, controlled by the vacuum valves. During the adsorption phase, the adsorbate flows from the evaporator to the adsorber, and heat is released there. Water is used as the heat transfer fluid in the developed AHP. Cold water is taken from the bottom of the accumulation reservoir, circulated inside the adsorber's tubes, and returned to the top of the reservoir, transferring the adsorption heat from the adsorber to the water in the accumulation reservoir. During the regeneration phase, the water flows from the adsorber to the gas burner, where it is heated, and circulated through the adsorber's tubes, providing heat required for the adsorbent to regeneration. At the end of the regeneration phase, the remaining hot water is delivered to the top of the accumulation reservoir. This setup enables the use of the gas burner as an instantaneous hot water heater, allowing the system to work in a direct heating mode when the hot water demands are extreme. According to computer simulations, this AHP system can reach a coefficient of performance of 1.35, which is aligned with results for other AHPs reported in the literature.

Keywords*— *Adsorption heat pump; adsorber; domestic water heating.

ACKNOWLEGEMENTS

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Development of a Passive Orthosis for Reducing the Load at Hip Joint

Tiago Rodrigues[(a),(b)], Jorge Ferreira [(c)], António Ramos [(c)]

(a) - Department of Physics, University of Aveiro; (b) - Neuromechanical Modeling and Engineering Lab, Biomechanical Engineering Department, Faculty of Engineering Technology, University of Twente; (c) - TEMA, Biomechanics Research Group, Department of Mechanical Engineering, University of Aveiro

(a) - Aveiro, Portugal; (b) - Enschede, Netherlands; (c) - Aveiro, Portugal

(a) - tiagoepr@ua.pt

Abstract — **Population aging is one of the most critical challenges in the near future, characterized by a low birth rate and a long-life expectation, especially in industrialized societies. In 40 years from now, nearly 35% of the European population will be over 60 years old, resulting in the urgency to provide solutions that allow our aging society to remain active, creative, productive, and independent. When the hip joint is damaged by arthritis, fractures, or other problems, some common daily activities, such as walking, sitting, or climbing stairs, become limited and quite painful for the subject. One of the ultimate solutions is an arthroplasty, which aims to replace, remodel, or realign a joint to relieve pain and restore mobility and the functional capacity. Nevertheless, with advancing age, bone osteolysis makes it necessary for a new replacement, which might be a risky procedure for elderly people [1].**

Among all the assistive devices springing up, wearable orthosis can be used to either augment, train, or supplement human motor function. Examples of such robots are exoskeletons, bionic prostheses, exosuits, and body-worn collaborative robots. A wearable orthosis is generally anthropomorphic, prepared to be comfortably worn by its user. Given the close interaction with the user, the orthosis should be light-weight and take in account the user's joints range of motion (ROM) and degrees of freedom (DOF), its morphology, and kinematics in the order it can provide a proper physical interface [2,3]. The existing passive exoskeletons, which use elastic elements in parallel with the lower limbs, allow to support part of the body weight to which the joints are subjected, storing, and redistributing energy along the limb. Several models have been developed however, one of the biggest remaining gaps is the transfer of load at the hip joint, which proves not to be a main objective in the development of current systems as they seek more assistance to movement or rehabilitation of muscular functions that support body mass.

In the present work, a model of a passive and light orthosis was developed, capable of transferring part of the load from the hip joint directly to the body of the femur. This helps to attenuate the longitudinal component of the force, thus reducing pain and patient's discomfort. CAD models and numerical studies were conducted using an offline model of the hip forces and a proof-of-concept prototype was also developed for experimental validation. The physical model uses a rigid ergonomic structure and an elastic energy accumulating device, in this case a spring, whose preload can be regulated for controlling the assistance's level. The numeric calculations demonstrated the adequacy of the model for a 20% reduction in the reaction force applied to the femoral head. The model was also validated by the preliminary experimental results with the prototype of concept.

The approached model represents a promising starting point for subsequent studies and progression for the practical and clinical field.

Keywords — Hip joint, Biomechanics, Passive exoskeleton, Hip orthosis, Load transfer

ACKNOWLEGEMENTS

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High affinity of 3D spongin scaffold towards Hg(II) in real waters.

Eddy M. Domingues [(a)], Gil Gonçalves [(a)] Bruno Henriques [(b,c)], Eduarda Pereira[(c)], Paula A. A. Marques [(a)],

(a) – TEMA, Mechanical Engineering Department, University of Aveiro; (b) – CESAM & Department of Chemistry, University of Aveiro; (c) – LAQV-REQUIMTE, Department of Chemistry & Central Laboratory of Analysis, University of Aveiro

(a, b, c) Aveiro, Portugal
(a) – eddy@ua.pt

***Abstract* – The presence of trace metals in water is a threat to the health of humans and to all forms of life. Among those metals, mercury (Hg) is considered the third most dangerous substance to human health [1]. It is thus essential to keep searching for new improved materials that can remove Hg from real water matrixes. Many natural materials have been proposed for this purpose [2], but almost all of these have in common the use unrealistically high initial concentration of Hg and the use of simple water matrixes, which are not representative for application in real-life conditions. Here we focus on the ability of commercial natural bath sponges, which are made from the skeletons of marine sponges to sorb Hg from natural waters. Marine sponges are an easily farmed, sustainable and eco-friendly source for a natural material. After bleaching the organic part of the natural sponge, the main component of these bath sponges is spongin, which is a type of collagen-based composite that combines with halogenated fibrillary structures and results in a compact tridimensional network of nano-fibrils. This natural scaffold offers a plenitude of reactive sites from the great variety of amino acids in the protein chains, where the Hg ions can sorb and it was never evaluated before for this purpose. For a dosage of 40 mg L^{-1} and initial concentration of 50 µg L^{-1} of Hg(II), marine spongin (MS) removed ~90% of Hg from 3 increasingly complex water matrixes (ultrapure, bottled, and seawater), corresponding to a residual concentration of ~5 µg L^{-1}, which tends to the recommend value for drinking water of 1 µg L^{-1} [3]. The efficiency was found to be independent of dosage, suggesting the existence of a concentration gradient threshold below which the Hg sorption mechanism is hindered. Kinetic modelling showed that the Pseudo Second-Order equation was the best fit for all the water matrixes, which indicates that the sorption mechanism relies most probably on chemical interactions between the functional groups of spongin and the Hg ions (hydrogen bonds and electrostatic interactions). The application of Weber's intraparticle-diffusion model suggests that the sorption process occurs in the two steps, where the first linear section is most probably related to a faster diffusion in the larger pores of MS samples, driven by the higher concentration gradient, and the second step indicates that the intraparticle-diffusion decreases with decreasing concentration gradient. The regeneration (in HNO_3) and reuse of this material was tested for 3 consecutive cycles with small losses in efficiency (less than 10%), in all the water matrixes tested.**

Keywords – Spongin, Mercury Remediation, Real Waters, Kinetic and Equilibrium Modelling.

ACKNOWLEGEMENTS

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3D reduced graphene oxide-based scaffolds with fibrous-porous architectures for neural tissue engineering applications

André F. Girão [(a)(b)], Joana Sousa [(a)], Ana Domínguez-Bajo [(b)], Ankor González-Mayorga [(c)], António Completo [(a)], María Concepción Serrano [(b)] and Paula A.A.P. Marques [(a)]*

(a) - TEMA, Department of Mechanical Engineering, University of Aveiro; (b) - Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas; (c) Hospital Nacional de Parapléjicos, Servicio de Salud de Castilla-La Mancha

(a) Aveiro, Portugal; (b) Madrid, Spain; (c) Toledo, Spain

*andrefgirao@ua.pt

Abstract — **Graphene-based scaffolds are gradually becoming prominent players on therapeutic strategies aiming the regeneration of injured neural tissues such as the spinal cord. Particularly, by modulating the oxidative state of graphene oxide (GO) porous systems, it is possible not only to directly influence the differentiation patterns of neural stem cells, but also to accurately control the adsorption of specific biomolecules towards the recreation of biomimetic chemical gradients. On the other hand, the incorporation of graphene-based nanomaterials into the polymer matrix of nanofibrous networks is capable of significantly boosting the guidance and outgrowth of neurites [1].**

Herein, we report a scaffolding methodology able to synergistically combine both fibrous and porous topographies and, consequently, promote a remarkable impact on the behavior of embryonic neural progenitor cells (ENPCs) in vitro [2]. Briefly, GO nanosheets were chemically reduced (rGO) and mixed within a polycaprolactone-gelatin (PCL-gelatin) solution before electrospinning. Although the resultant PCL-gelatin-rGO nanofibres were able to instigate a better cell response comparatively to the PCL-gelatin nanofibrous mesh, both electrospun networks were tested as physical crosslinkers for rGO sheets, leading to the generation of hydrogel-like structures. After lyophilization, both 3D systems showed a suitable accommodation of the respective nanofibres onto the surfaces of rGO heterogeneous porous networks. In the same way, independently of the nanofibrous composition, both 3D fibrous-porous systems supported an efficient adhesion of ENPCs and their consequent differentiation into viable neuronal and non-neuronal cell types. Additionally, during 14 days in culture, the biochemical and topographical cues provided by these scaffolds stimulated neurite outgrowth and elongation, generating interconnected neural networks. Nevertheless, the presence of rGO in the PCL-gelatin-rGO nanofibres markedly influenced the attraction/repulsion forces established during the hydrogel synthesis, influencing the mechanical compliance, swelling ability and porosity of the final 3D fibrous-porous system. This result may be crucial for upcoming in vivo studies, in which 3D fibrous-porous scaffolds should be able to recreate a specific structural/mechanical integrity as well as the porous structure of the targeted region of the injured spinal cord.

Taking all this into account, the reported scaffolding approach presents the capability of developing dual 3D fibrous-porous architectures suitable for supporting the formation of highly viable neuronal circuits in vitro. Furthermore, considering the feasibility on adjusting the properties of such scaffolds, it is reasonable to consider their integration on diverse strategies for neural tissue engineering applications.

Keywords — Neural tissue engineering; Graphene; Scaffold

ACKNOWLEGEMENTS

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Automated manufacture of anisotropic electrospun scaffolds towards articular cartilage repair

Ângela Semitela [(a)], Andreia Leal Pereira [(a)], Ana Capitão [(b)], Alexandrina Mendes [(b)], Paula A.A.P. Marques [(a)] and António Completo [(a)]
(a) –TEMA, Department of Mechanical Engineering, University of Aveiro, Portugal
(b) –CNC, Centre for Neuroscience and Cell Biology, University of Coimbra, Portugal
(a) – Aveiro, Portugal; (b) – Coimbra, Portugal
(a) – angela.semitela@ua.pt

***Abstract* — To date, cartilage tissue engineering (TE) strategies have had some success, developing replacement tissue constructs for articular cartilage. Yet, most of these tissue-engineered constructs do not possess a native layered structure, particularly the collagen fibers alignment, progressing from parallel in the superficial zone, to random in the middle zone, and finally orientating perpendicular in the deep zone [1]. Given the nanofibrous topography of these collagen fibres, electrospinning has been widely employed for the development of fibrous scaffolds for cartilage TE [2]. Still, it remains a challenge to develop three-dimensional (3D) electrospun scaffolds with a specific depth-dependent fibrous alignment, as well as a uniform chondrocyte distribution. While some progress has been made in the development of these 3D anisotropic electrospun scaffolds by means of post-processing strategies of the electrospun meshes, several concerns still remain, particularly the design reproducibility and the ineffective chondrocyte infiltration [3].**

So, in this work, we attempt to fabricate chondrocyte-laden 3D anisotropic electrospun scaffolds in a totally automated manner using a newly developed electromechanically 3D electrospinning platform [4], in order to develop functional articular cartilage tissue constructs.

A polymeric blend of polycaprolactone (PCL) and Gelatin (GEL) was employed, and the PCL+GEL fibres were collected and placed in a collector to adjust fibre alignment. An immortalized human chondrocyte cell line C28/I2 was pipetted between the fibrous layers. Chondrocyte-laden scaffolds were cultured under static and perfused conditions for 21 days. The 3D scaffolds and the respective cell-seeded constructs were characterized based on their topographic, mechanical and biological properties.

The 3D scaffolds were successfully fabricated with a slight arcade-like fibrous arrangement, while maintaining a high level of porosity. This was particularly important for an effective nutrient delivery and waste removal during culture, even under static conditions, where this is only performed via molecules diffusion. Moreover, the 3D scaffolds possessed an enhanced water absorption capacity, related not only with the elevated porosity, but also with the presence of the hydrophilic GEL, translating in a nearly total deformation recovery after compression at 20%. The *in vitro* results demonstrated that, even though a substantially low percentage of viable chondrocytes was observed after 1 day of culture, the remaining chondrocytes were able to proliferate over time. Additionally, under perfused conditions, the percentage of viable cells was significantly higher, suggesting its beneficial impact of chondrocyte metabolism. The compression modulus of the 3D scaffolds fell in the range of values reported for native articular cartilage, and it was significantly increased upon culture under perfused conditions, suggesting that flow perfusion enhanced chondrocyte synthesis of extracellular matrix elements, which translated in an increased biomechanical strength of the chondrocyte-laden 3D scaffolds.

Keywords* — *Cartilage tissue engineering, 3D electrospun scaffolds, Anisotropic, Chondrocyte-laden.

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Experimental and numerical investigation

On the characterization of a transcritical CO_2 variable-speed scroll compressor

Francisco Bispo Lamas [(a)], V. A. F. Costa [(b)]
(a, b) - Departamento de Engenharia Mecânica; Universidade de Aveiro
(a) Aveiro, Portugal
(a) - francisco.lamas@ua.pt

***Abstract* — This work aims at presenting an experimental and numerical investigation on the characterization of a variable-speed scroll-type compressor used in a transcritical CO_2 heat pump (TCO2HP) water heater. Building on the progress made so far, regarding the characterization and development of numerical models for all TCO2HP components, the results from this work allow to complete and validate the entire system's model.**

Common compressor models provide both mass flow rate and electric input power based on the isentropic, volumetric, and global efficiencies (through correlations based on the discharge to suction pressure ratio), rotational speed, swept volume, and on refrigerant conditions at compressor's inlet and outlet (density and specific enthalpy). On the other hand, the black-box AHRI model type, a ten-coefficient polynomial approach, provides the same information based on compressor's suction and discharge temperatures, and on experimentally obtained compressor map coefficients. As presented, each model type requires information from the compressor manufacturer that might not be available.

An experimental test campaign has been carried out, in the Climatic Laboratory at Bosch facilities (Aveiro, Portugal), providing information for the characterization and model validation of the TCO2HP. The external environmental conditions, covering a wide span of air temperature and relative humidity test points, were attained by a climatic chamber. Data acquisition and information processing were managed by a small test rig, originally equipped for EN16147 performance tests evaluation. Temperature probes, an electrical power meter, a water pump and two flowmeters, airside velocity and pressure probes composed the measurement system. Owing to budgetary restrictions, no refrigerant mass flowmeter nor pressure gauges were installed, substantially impoverishing the potential of the results for model validation. Furthermore, and contrarily to subcritical vapor compression cycles which can be defined by two pressure levels – evaporation and condensation (isothermal and isobaric two-phase flow processes), supercritical gas cooling pressure cannot be related with the corresponding (saturation) temperature.

An algorithm has been developed to identify stationary periods from the experimental tests performed with the TCO2HP. Different criteria, such as sharped variations on the compressor power input and on water temperature at the gas cooler, enabled the identification of different working patterns, and the evaluation of average fluid temperatures (refrigerant, water and air) and electric consumption, during those periods. Additional correlations based on the available heat pump datasheets were introduced in the algorithm, allowing the estimation of heating capacity, coefficient of performance (COP), water flowrate and electric power input, all as functions of the water temperature difference in the gas cooler. The last two were later validated by comparing with experimental data, presenting only negligible deviation errors. An important result, the refrigerant mass flow rate, was also extracted from the algorithm (even if in a rough estimation).

Posteriorly, using both estimated heating capacity and the average measured refrigerant temperatures, a trial-and-error process was performed using an EES application, to determine the most suitable isentropic and global efficiency, matching the prior estimated COP and refrigerant mass flowrate, and measured electric power input. Thus, providing the necessary information for the compressor characterization and the whole system model's validation.

Keywords* — *Transcritical CO_2; heat pump; compressor characterization.

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TOPIC

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

Performance evaluation of different control strategies for tankless gas water heaters

Ismael Ehtiwesh [a, b], André Quintã [a], Jorge Ferreira [a]
[a] TEMA; Department of Mechanical Engineering; University of Aveiro
[b] Faculty of Engineering; Department of Mechanical Engineering; Sabratha University
[a] Aveiro, Portugal; [b] Sabratha, Libya
[a, b] ehtiwesh@ua.pt

***Abstract* — The production of domestic hot water is responsible for a significant part of domestic energy consumption; instantaneous gas heating devices are widely used [1] due to no reservoir is needed, smaller size, continuous hot water flow, longer estimated life, and lower energy consumption [2]. Therefore, it has a competitive use/consumption ratio compared to other technologies. However, users' perception of comfort is severely affected by sudden changes in temperature apart from the desired temperature. The instability of the water temperature, with overshoots and undershoots, is the most common drawback that occurs mainly due to sudden changes in the water flow demanded by users and the response delays inherent to the heating device. Classical heat cell power controllers have difficulties in responding to these troubles in a timely manner [3,4] because they do not have the capacity to anticipate the effects of sudden variations in water flow rate. In the present study, predictive control strategies were developed which, due to their predictive nature [5], allows anticipating and correcting the negative effects of sudden variations of water flow rate in the temperature. A comparative analysis of model-based predictive controllers (MPCs), with and without adaptive function, with a conventional controller, a Feedforward PID, normally used in tankless gas water heaters (TGWHs) was carried out using the Matlab and Simulink tools. Adaptive model predictive control, among others, presents a superior performance in temperature stabilization, especially during sudden flow rate changes. However, the opening of TGWH manufacturers to the use of these control techniques requires their implementation in low-cost microcontrollers that have limited computational and memory resources. In this context, the following step of this work was to develop a low computational algorithm that can be embedded into low-cost hardware; an adaptive MPC being the results very promising when the time sample is equal to one second. However, it is still required further optimizations under the ongoing research to fulfill the objectives of reducing the time sampling to 250 ms (commonly used by manufacturers, in particular, Bosch Termotecnologia). Based on the developed algorithm, the next step aims to address the embedded hardware implementation, in order to perform the virtual and real control evaluation tests.**

Keywords* — *tankless hot water production; predictive control strategies; adaptive control; low-cost embedded control.

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3D anisotropic scaffolds for spinal cord regeneration

Joana P.M. Sousa [(a)(b)(c)], Sara C. Santos [(b)], Catarina A. Custódio [(b)], Emmanuel Stratakis [(c)], João F. Mano [(b)] and Paula A.A.P. Marques [(a)]*

(a) - TEMA, Department of Mechanical Engineering, University of Aveiro; (b) - CICECO, Department of Chemistry, University of Aveiro; (c) – Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology-Hellas (FORTH)

(a) and (b) Aveiro, Portugal; (c) Heraklion, Greece

*joanapmsousa@ua.pt

***Abstract* — Spinal cord injury is defined as a damage to the spinal cord that causes changes in its function and can mean permanent loss of functionality at the sensory and motor level affecting, for example, locomotion, breathing, heart rate, sexual function and bowel and bladder control, resulting in psychological and social consequences devastating for patients worldwide [1].**

Currently, there is no treatment capable of fully restore spinal cord physiology, and patients' well-being is ensured by palliative and rehabilitation approaches. In this regard, neural tissue engineering offers an opportunity to associate cells, biomolecules, biomaterials and microfabrication techniques to reconnect the two stumps of the injury [2]. Considering tissue organization, the core of spinal cord - grey matter - consists mainly of randomly distributed nerve cell bodies, myelinic fibres and glial cells, while the periphery is composed of aligned motor and sensory axon tracts - white matter – that are responsible for the conduction of neural information through electrical impulses. A lesion to the spinal cord may result in tissue disruption, loss of blood supply, death of neural cells and scar formation [3] Particularly, the damage to the white matter has been shown to prevent axon extension across the injured area blocking the restoration of the neuronal network [4]. To overcome this inhibitory environment, some tissue engineering approaches are specifically focused on mimicking the white matter alignment via the design of 3D anisotropic scaffolds. Those scaffolds can be divided in three major categories according to their micro/nanostructure: vertically aligned fibres, vertically aligned pores and multichannel scaffolds.

Here, we summarize and discuss the features, fabrication techniques, and reported impacts on spinal cord regeneration of each category and present our own strategies for the fabrication of 3D scaffolds to promote aligned tissue regrowth between the proximal and distal ends of the injury.

Keywords* — *Spinal cord injury; Tissue Engineering; Scaffold; Anisotropic

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Embedded implementation of predictive control strategies for gas-fired instantaneous water heaters

André Quintã [(a)], Ismael Ehtiwesh [(a,b)], Nelson Martins [(a)], Jorge Ferreira [(a)]

(a) - Centre for Mechanical Technology and Engineering (TEMA), Department of Mechanical Engineering; University of Aveiro; (c) - Faculty of Engineering; Sabratha University

(a) Aveiro, Portugal; (b) Sabratha, Libya

(a) - aquinta@ua.pt

***Abstract*— Domestic water heating is a major component of buildings energy consumption, where tankless gas water heaters (TGWH), also referred as gas-fired instantaneous, are extensively used. One of the most relevant drawbacks of TGWH is the difficulty to control the outlet hot water temperature, as changes in water flow rate can be quick and unpredictable leading to temperatures overshoots and undershoots that severely affect the comfort perception by the user, increasing water and energy waste [1], [2].**

Current TGWH commercial appliances have gas and air modulation, water flow and temperature sensors integrated in electronic control units (ECU). Usually, conventional control approaches are proportional-integral-derivative (PID) feedback controllers or a combination between feedback and feedforward control, characterized by a competent performance on steady state regime but unsatisfactory during transient periods.

Several strategies were proposed to improve TGWH water temperature stabilization, some based on additional hardware, such as a cold-water bypass circuit, mixing valves or internal tanks, others based on more advanced and robust control strategies, such as fuzzy control and genetic algorithms. One of the most promissory approaches to improve TGWH temperature stabilization is the model predictive control (MPC) [3], [4].

In this work, the development of predictive algorithms and strategies for the TGWH temperature stabilization problem, are presented and evaluated. The embedded implementation of MPC strategies is particularly challenging, due to the severe computational limitations of the ECU, such in terms of memory as in terms of processing speed for real time control. Automatic code generation techniques are used to program microcontrollers. The first tests were performed on the popular low-cost platform Arduino, and later implemented on the ECU of a commercial appliance, based on a Renesas 16 bits microcontroller. Hardware-in-the-loop-simulation (HILS) methodologies were used for the performance evaluation of feedback, combined feedback-feedforward, and MPC control strategies embedded in the microcontroller.

Although the embedded implementation of MPC on ECU with limited computational resources reveals to be a complex task, preliminary results show improved performance compared with conventional control.

Keywords*— *domestic hot water; tankless gas water heaters; instantaneous gas-fired; model predictive control; embedded; real time; hardware-in-the-loop-simulation

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Development of a new classification system for Mobility as a Service platforms

João Teixeira, Eloísa Macedo, Jorge M. Bandeira
Dept. Mechanical Engineering; TEMA – Centre for Mechanical Technology and Automation
University of Aveiro, Aveiro, Portugal
jpteixeira@ua.pt, macedo@ua.pt, jorgebandeira@ua.pt

***Abstract* — The concept of Mobility as a Service (MaaS) has received great attention and interest from various sectors such as, governments, industry, researchers, public. MaaS offers an integrated and user-oriented application in which multiple mobility choices are provided in an attempt to fulfill user mobility needs and be an attractive alternative to the use of the private car. This framework is often considered fundamental for a more sustainable and inclusive transport system [1]. Recently, a MaaS topology was proposed to better compare MaaS services [2]: Level 0: No integration of transport modes; Level 1: Integration of transport modes, Level 2: Integration of booking and payment; Level 3: Integration of service offer subscription, contracts and responsibilities; Level 4: Integration of Societal Goals. However, this classification is cumulative and societal goals are only considered in the highest integration level.**

Although it is true that the increase of Mobility choices options is often associated with reduced dependency on the individual car, it is important to be aware of the unintended consequence of MaaS which may compromise the goal of sustainable cities [3]. Many authors expect perverse and unanticipated outcomes with a broad expansion of MaaS which may influence travel behavior, changes in land use, land value affecting urban form as different impacts on different social groups [4-6]. Frequently the public sector is pointed as the key enabler of this mobility packages service [7-8]. However, MaaS is a concept dependent of applications through ICT integration that is dedicated to existing social movement as peer-to-peer sharing, arising the application of mobile ICTs, which is rather commercial than social [9]. Therefore, barriers such as individual, organizational and societal approaches will be dependent on how well public authorities on city, regional or national level can influence user's behavior by setting the right conditions, so the users follow the desired societal behavior expected by future governances [2,10].

Currently, MaaS services are characterized in such a way that it is difficult for users, planners and policymakers to assess clearly and unequivocally the level of coverage, multimodality, available services and integration of active policies to promote sustainability.

Through statistical analysis and clustering techniques based on the analysis of 120 mobility services in six countries within the PriMaaS partnership, a new classification system is proposed by the team mainly focused on four fundamental dimensions: Multimodality, Coverage, Functionalities and Sustainability.

Keywords — ICT, MaaS, Societal Goal, Integration

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New opportunities for 3D Printing at TEMA

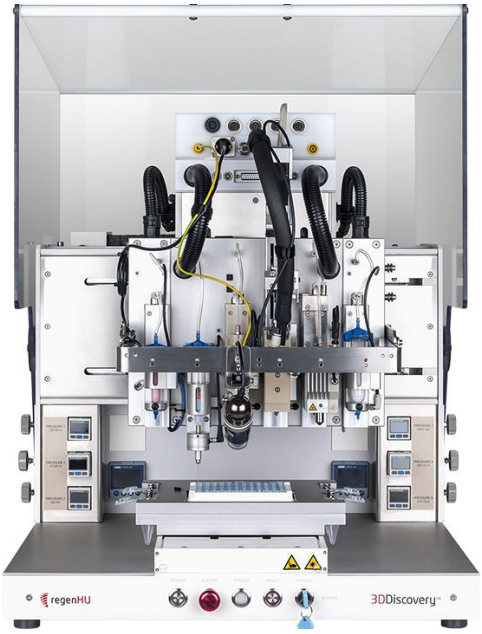
Wanna know more?

Nathalie Barroca [(a)] and Paula A. A. P. Marques [(a)]
(a) – Centre for Mechanical Technology and Automation – TEMA, Department of Mechanical Engineering, University of Aveiro; Aveiro; Portugal
nbarroca@ua.pt, paulam@ua.pt

***Abstract* — 3D printing has recently emerged as a real game changer in everyday life applications and high-end technologies across several areas. Among the plethora of additive manufacturing technologies, this talk summarizes the novel techniques available within the BioDiscovery 3D Printer from Regenhu, recently acquired within the European FET-OPEN project NeuroStimSpinal. This 3D printer presents 3 pneumatic dispensing-based extrusion heads and gathers several technologies.**

Multi-material devices can be printed by combining slurry, solution extrusion, microvalve based printing, electrohydrodynamic jet printing and melt electrowriting. All these technologies can further integrate UV-assisted curing. Targeted applications go from flexible electronics to high resolution sensors, energy harvesting, micro-optical components, and regenerative medicine. The system is equipped with a class II biosafety cabinet, suitable for bioinks to print anatomical size acellular devices but also scaffolding strategies with precise spatial control of cell deposition within the constructs.

Keywords*— *3D printing; extrusion based bioprinting; melt electrowriting; electrohydrodynamic jet printing



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TOPIC

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

Real driving emissions in passenger cars

Developing new predicting models based on engine parameters and driving volatility indicators

Paulo Fernandes [(a)], Ricardo Tomás [(a)], Eloísa Macedo [(a)], Elisabete Ferreira [(a)], Behnam Bahmankhah [(a)], Jorge M. Bandeira [(a)], Margarida C. Coelho [(a)]

(a) – Department of Mechanical Engineering, Centre for Mechanical technology and Automation, University of Aveiro

(a) Aveiro, Portugal

(a) – paulo.fernandes@ua.pt

***Abstract*—Past research has revealed that on-road tailpipe emissions in passenger vehicles exceed the official laboratory-test values. These concerns have prompted the increasing use of Portable Emissions Monitoring System (PEMS), but the direct use of Internally Observable Variables (IOVs) and driving volatility indicators can be useful to predict emissions. The motivation for this paper is to develop an empirical approach that integrates second-by-second vehicle emission rates and vehicle activity data for passenger cars. The specific objectives are two-fold: i) to examine the correlation between IOV-based predictors of engine load and driving volatility, and carbon dioxide (CO_2) and nitrogen emission rates (NOx); ii) to compare the performance of the proposed models to a Vehicle Specific Power (VSP) modal approach. IOVs models were developed on the basis of the product of manifold absolute pressure (MAP) and engine revolutions per minute (RPM) while driver volatility was measured by vehicle acceleration and vehicular jerk (i.e., the first derivate of acceleration). For the latter case, dynamic emission models represented by nine driving behaviours associated with vehicular jerk classification were proposed. Field measurements were collected from five passenger cars (two small, one medium, one SUV, and one multi-purpose) in urban, rural, and highway routes using PEMS, Global Positioning System receivers and On-board Diagnostic scan tool, to measure real-world exhaust emissions and engine activity data. IOVs models showed to be good predictors of emission rates, for instance, in diesel passenger cars. Although these kinds of models were as good as the VSP-based modal approach in predicting CO_2 emission rates (R^2 ranged from 0.46 to 0.74, depending on the vehicle), they were worse in predicting NOx emission for small vehicle categories ($R^2 < 0.60$). This happened because the operating conditions of Selective Catalytic Reduction were not considered in the NOx model. Results also indicated that driving volatility-based models using engine speed as input were good predictors of CO_2 (R^2 ranged from 0.77 to 0.96, depending on the jerk type) in one hybrid electric vehicle for both internal combustion engine states. However, the predicted emissions of NOx resulted in values of R^2 lower than 0.57, owing to the proportion of measured concentrations that were below the instrument detection limit. A comparison with VSP confirmed that driving volatility-based models resulted in better CO_2 predictions (1% to 16%, depending on the trip). In turn, the differences between VSP and measured values ranged from 7% to 25%, depending on the trip. The analysis of NOx estimates also confirmed that the proposed models were aligned with VSP for almost all trips. VSP-modal approach resulted in a higher overestimation of field NOx (8-15 times on average) than the driving volatility-based approach (2-3 times on average). Both IOV-s and driving volatility-based models have potential to be integrated into vehicle engine units and connected vehicles to provide real-time information on emissions rates associated with volatile driving. These classifications would allow for better energy efficiency and eco-efficient driving behaviour controls. However, other parameters regarding the thermal management on after treatment system must be included in NOx prediction.**

***Keywords*— Passenger Cars; Tailpipe Emissions; Predictive Models; Internally Observable Variables; Driving Volatility.**

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TOPIC

2) Technologies for the Wellbeing
   b. Innovative Technologies for Smart Cities.

An Integrated Assessment of Road Traffic Noise and Pollutants Critical Hotspots through Advanced Models

Antonio Pascale [(a)], Claudio Guarnaccia [(b)], Margarida C. Coelho [(a)]

(a) Department of Mechanical Engineering / Centre for Mechanical Technology and Automation (TEMA); University of Aveiro; (b) – Department of Civil Engineering; University of Salerno

(a) Aveiro, Portugal; (b) – Fisciano, Italy

(a) – a.pascale@ua.pt, margarida.coelho@ua.pt; (b) – cguarnaccia@unisa.it

***Abstract* — This communication aims to present the PhD. research plan entitled "An Integrated Assessment of Road Traffic Noise and Pollutants Critical Hotspots through Advanced Models". The PhD. proposal arises from the need to estimate road traffic noise and pollutants emissions in an integrated way. In fact, as stated by the European Environment Agency, noise and air pollution are the two most important environmental issues in Europe [1], and road transportation sector strongly contributes to them. Moreover, although road traffic-related noise and pollutant emissions depend on common variables, such as (but not limited to) vehicles speed, acceleration, vehicular jerk (i.e., acceleration time derivative), road gradient, road surface, vehicle type and motorization, tyres pressure and dimension, the effect of these latter on the former is not the same. Furthermore, only few studies focus on the combined evaluation of traffic noise and pollutant emissions [2], making necessary further and more detailed investigations on this topic.**

The main objective of the Doctoral plan is the development of a Noise Emission Model called Vehicle Noise Specific Power (VNSP) [3]. Following the idea behind the Vehicle Specific Power (VSP) methodology [4], it will allow to estimate the source sound power level (L_w) for different categories of vehicles (namely, passenger cars, VANs, motorcycles and heavy-duty vehicles) by considering the above mentioned variables as inputs. Specifically, the plan aims to: 1) Introduce in the VNSP a classification based also on vehicle motorization (gasoline, diesel, hybrid or electric), to capture the noise emissions variability in the low speed range (below 40 km/h) where the engine noise contribution is predominant; 2) Develop a Road Traffic Noise Microscopic Model (RTNMM) based on the VNSP able to estimate the equivalent continuous sound power level (L_{eq}) produced by the road traffic flow in different time ranges, by considering the source-receiver distance, the vehicle typology and motorization, microscopic kinematic variables and road parameters; 3) Develop noise and pollutants maps built on integrate use of RTNMM and VSP methodology, which could allow to: i) detect critical hotspots in terms of noise and pollutants; ii) evaluate the number of people exposed to noise levels and pollutants concentration exceeding the limits; iii) help the policymaker in the in the enaction of action plans; iv) create paths completely dedicated to micromobility users (e.g. pedestrians, cyclists and e-scooters users) located far away the hotspots.

Keywords* — *Vehicle Noise Specific Power; Road Traffic Microscopic Model; Noise Maps; Pollutants Maps.

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Adaptive Control Strategy for Efficient Conversion of Photovoltaic Energy to Mechanical Work

An Innovative Scheme for Maximum Power Point Tracking and Optimal Load Modulation

Luís S. Rodrigues✉, Jorge A. F. Ferreira, Fernando Neto, Nelson Martins
Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro
Aveiro, Portugal
✉lrodrigues@ua.pt

***Abstract* — Naturally occurring fluctuations in solar irradiance (W/m^2) – predictable (e.g., time of day) or not (e.g., clouds) – pose challenging difficulties for the optimal conversion of photovoltaic energy to mechanical work, since the output voltage at the source correlates very poorly with the instantaneously available maximum power point (MPP) [1]. Unfortunately, the open circuit voltage (V_{oc}) remains almost unchanged throughout a wide range of MPPs and is mostly influenced by the temperature of the photovoltaic cells and, to a lesser extent, by the age of the cells and the spectral distribution of the incident radiation [2].**

Ideally, to maximize the utilization of the available energy, the load should always work at the MPP voltage and current (V_{mp} and I_{mp}, respectively), tracking the respective variations. This cannot be achieved with a fixed or passive load. Fortunately, in solar-powered applications where mechanical work is the goal (e.g., water pumping, cooling, etc.), the load power can be modulated by controlling the speed and/or torque of an electrical motor by means of a variable frequency drive circuit (VFD). Fortunately, the types of motor that allow this type of control – e.g., brushless DC, synchronous AC and asynchronous/induction – are also the most efficient types, with efficiencies comfortably above 90% (even 96% in some cases).

However, two problems remain: (i) determining if there is enough power available to start and sustain the motor (intermittent starts can be problematic in some applications, e.g., cooling), and (ii) finding the optimal working point. Hunting for this point by changing the driving frequency by trial and error is far from an optimal strategy and can result in motor stall conditions (which, again, can be critical in cooling applications). To solve both these problems, the instantaneous MPP should be, ideally, continuously measured. However, the MPP cannot be calculated from V_{oc} and can only be roughly estimated by measuring the short-circuit current (I_{sc}). To accurately find the MPP, the range of output current-voltage combinations should be scanned. Executing this measurement without interrupting the supply to the load presents yet another challenge.

The implemented solution is comprised of a specially designed electronic circuit for measuring the power curve of a photovoltaic source while maintaining a constant supply to the load – without resourcing to an electrochemical battery – and an adaptive control algorithm for modulating the driving frequency of a brushless motor to maximize energy utilization. A practical prototype was built for optimizing the efficiency of a solar-powered chest freezer equipped with an asynchronous AC motor and a variable frequency drive (VFD).

Keywords — Photovoltaic Energy, Efficiency Optimization, Adaptive Control, Maximum Power Point Tracking (MPPT), Load Modulation.

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Engineering self-regulating construct-bioreactor to model the dynamic microenvironments of realistic tumors

Integrated tumor-on-a-Chip (IToC)

João F. Gil [a,b], Carla Moura[a], Vania Silverio [b] , Gil Gonçalves[c]

(a) - Centre for Rapid and Sustainable Product Development (CDRSP-PLeiria); (b) - INESC Microsystems and Nanotechnologies, INESC-MN, and IN; (c) - Centre for Mechanical Technology and Automation (TEMA), Mechanical Engineering Department; University of Aveiro

(a) Marinha Grande, Portugal; (b) – Lisboa, Portugal; (c) – Aveiro, Portugal

(c) – ggoncalves@ua.pt

***Abstract* — Tumor-on-a-Chip (ToC), which are microfluidic devices aiming at mimicking important features of the tumors physiology, are good examples of nanotechnology applications combining micro/nanofabrication tools, microfluidics, tissue engineering and three-dimensional (3D) bioprinting [1]. ToC technology provides an effective solution to recreate patient-specific tumor models to tackle fundamental studies of physical properties of tissue, diagnostic tools and therapeutic planning, to name a few. However, ToC are so far simple, lacking the integration of multiple components as tumor microenvironment, multiple cell types, extra cellular matrix (ECM) and vasculature with complex spatiotemporal distribution to achieve real functional microtissues.**

This work aims to develop an integrated ToC (construct-bioreactor) to address the multiscale problem combining scaffold-based tissue engineering (TE) and bioprinting (centimeter scale) with micro/nanofabricated ToC and microfluidics technology (micro/nanometer scale) to study realistic 3D tumor models. The ToC microarchitecture will be supported by micro/nanofabrication for an automatized integrated system on a chip incorporating microfluidic passages for vascularization, sensing elements for detection of biomechanical properties change and biochemical signalling, electronics, microfluidic-enhanced bioprinting parts and visualization through confocal microscopy. These ToC will be stacked and combined with a 3D bioprinted scaffold to address the spatial, structural and dynamical complexity, typical of 3D tumor tissues. Breast tumor cells will be used due to the existing extensive literature of their properties and responses [2,3]. The optical properties of the materials to be used will provide a facilitated access to the tumor for mechanotransduction studies.

Integrating ToC and TE will allow to accurately emulate the architecture and the physiology of the solid tumor in a more sophisticated and effective way. Self-regulating constructs with mimicked microenvironment and dedicated vascularization able to continuously feed nutrients and oxygen and sensing and monitoring of biophysical/biochemical cues during all stages of the tumor development will be made possible with this innovative design. This novel approach aspires to propose a realistic tumor-like construct with relevant features that can be explored to obtain predictive models. The models will support the fundamental study about the mechanisms by which mechanical cues integrate with biochemical signals from the microenvironment, and the underlying mechanotransduction pathways involved in tumor progression.

This novel technology will provide fundamental knowledge that allows to correlate the structural features of the tumor with its progression and severity by exploring the current diagnostic methods. Moreover, these realistic 3D-integrated tumor models can become powerful enablers of higher-throughput screening of early-stage anti-cancer drugs, easily replacing the routine in vivo tests which present high costs, are time consuming and have strong ethical issues.

Keywords— nanotechnology; 3D bioprinting; tumor-on-chip, cancer;

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Household Thermal Energy Storage in the Context of Smart Grids

Viability and Potential Impact of Small Residential Consumers in Demand-Side Load Balancing With The Use of Phase-Change Materials

Luís S. Rodrigues✉*, Jorge A. F. Ferreira, Vítor A. F. Costa*
Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro
Aveiro, Portugal
✉lrodrigues@ua.pt

***Abstract* — A *smart grid* can be defined as an electrical network equipped with distributed and interconnected automation technologies, in order to: (i) increase the efficiency, (ii) minimize waste and emissions, (iii) make the most of the installed infrastructure, and (iv) maximize the utilization of available renewable energy sources. It is a holistic concept that involves all the energy chain, from producers to consumers [1–3].**

The evolution towards smarter electrical grids is inevitable in the current global conjuncture of circumstances, among others: (i) the capacity limitations, high losses, and lack of reliability, caused by an ageing transport and distribution infrastructure; (ii) the increasing supply fluctuations induced by the growing penetration of renewable sources (mainly wind and solar); (iii) the increasing global demand from developing countries, etc...

The main objective of grid management is to match supply and demand. Smart grid technologies help to achieve this goal by allowing control from the demand side, impossible to achieve with conventional/classical control models (which rely exclusively on supply modulation). For this purpose, smart grids incorporate the more recent advances in information and communication technologies (ICT) to gather and consolidate the relevant information from all the intervenient players in the energy chain.

Demand-side load management (DSLM) has been, so far, exclusively assured by *big* consumers (e.g., industry, big office and/or commercial buildings, etc.). However, the participation of small residential consumers may become viable thanks to the dissemination of internet connectivity, the growing park of installed *smart meters* with telematic capabilities [4], the emergence of *Internet of Things* (IoT) technologies, the increasing number of electrical vehicles (EVs), and the profusion of microprocessor-controlled domestic appliances.

Shifting the load from peak to off-peak periods depends primarily on the capacity of delaying/postponing consumption. This capability is significantly augmented by the possibility of local energy storage. Unfortunately, the large-scale use of electrochemical batteries for this purpose is hindered by their economic and environmental costs. By contrast, the use of phase-change materials (PCMs) for thermal energy storage (TES) is by far cheaper and environmental benign [5]. TES has, easily, the lowest specific cost (i.e., $/kWh) of any type of battery [6]. The use of PCMs can even provide roughly twice the specific capacity (i.e., Wh/kg) of the most common and less expensive *lead-acid* battery [7]. Arguably, the major limitation of TES is that the stored energy cannot be, realistically, converted back to electricity. This limits its scope to thermal applications – i.e., water heaters, refrigerators, freezers, and space heating, ventilation, and air conditioning (HVAC). However, this does not diminish its importance, since, in most homes, the highest energy consumption results from water heating – which frequently coincides with peak hours – and, in many climates, from HVAC. Hence, together with refrigerators and freezers, domestic TES with PCMs will be, inescapably, part of a smarter energy management paradigm, towards a greener World.

Keywords — Smart Grids; Load Shifting; Demand-Side Load Management (DSLM); Thermal Energy Storage (TES); Phase-Change Materials (PCMs).

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Evaluation of Impacts on Intercity Corridors for Efficient and Sustainable Mobility

Innovative Ways to Address Corridors Pricing

Carlos Sampaio [(a)], Margarida C. Coelho [(a)], Eloísa Macedo [(a)] and Jorge M. Bandeira [(a)]
(a) University of Aveiro, Dept. Mechanical Engineering; Centre for Mechanical Technology and Automation
(a) Aveiro, Portugal
(a) – {c.sampaio; margarida.coelho; macedo; jorgebandeira}@ua.pt

***Abstract*—Regional transport and intercity trips represent a significant part of the total of the negative externalities related with transport sector. In Portugal, 65% of the kilometers travelled correspond to intercity movements, which in turn represent approximately 55% of both CO_2 and NO_x emissions [1].**

This work is intended to provide a description of a PhD research and to present preliminary results. The main objective is to develop tools and methodologies based on smart and dynamic tolls implementation to perform traffic assignment with the ultimate goal to mitigate the negative externalities associated with intercity corridors. The two main central research questions that will be addressed are to: 1) assess how an optimal traffic distribution in intercity corridors may support the transport-related externalities; 2) assess how new smart and dynamic tolls and fares may contribute to optimal traffic solutions.

The following general methodology will be applied:

1) Multimodal transport model, usage of external sources (such as OD matrixes, public transport options, average speed, among others) to develop a multimodal transport model; this will be the base of the methodology.

2) Macroscopic emission and noise modelling; in particular, real data will be used to calibrate the models.

3) Assessment of community exposure to traffic externalities, such as noise and local pollutants.

4) Internalization of the traffic related impacts such as emissions, noise, and road safety [2].

5) Optimal flows distributions.

6) Study and design of smart and innovative pricing strategies.

Research has been conducted and some preliminary results will be presented. The case study of the intercity corridor between Aveiro and Coimbra has two main road options (one highway and one national road). The baseline scenario for peak and off-hours were already concluded. Considering only the passenger traffic in the intercity corridor, during a typical peak hour, approximately 24 ton. CO_2 and 0.08 ton. NO_x are produced, while in a typical off-peak hour, such values decrease, reaching approximately 17 ton. CO_2 and 0.06 ton. NO_x. A first approach on the study of new strategies to decrease emissions consisted in decreasing and increasing the flat electronic toll collection. Results showed an increase of 5%, 7.5% and 10% in the tolls may lead to a reduction in both CO_2 and NO_x emissions. While a flat increase of the toll costs may seem perceived as unfair to users, preliminary results show that it is possible to decrease the emissions of the intercity corridor without increasing the user costs with tolls by implementing a GPS based-toll collection that represents the CO_2 external costs.

For future work, the modelling of traffic related impacts will focus on assessing the noise and crashes/safety components; characterization of community exposure; optimal flow distributions and optimal pricing strategies.

Keywords— Intercity Corridors; Emissions modelling.

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Carpooling as a Strategy to Urban Mobility During Public Health Threats: A Case Study in a University Campus

Ricardo Tomás [(a)], Paulo Fernandes [(a)], Joaquim Macedo [(b)], Margarida C. Coelho [(a)]

(a) - Dept. Mechanical Engineering / Centre for Mechanical Technology and Automation (TEMA), University of Aveiro;
(b) - Dept. Civil Engineering / Aveiro Research Center for Risks and Sustainability in Construction (RISCO), University of Aveiro
Aveiro, Portugal
(a) – ricardotomas@ua.pt

***Abstract* — The implementation of carpooling in different types of scenarios has shown positive outcomes, such as the reduction of pollutants emissions and the improvement of road traffic performance [1,2]. University campuses are small cities which serve as perfect case studies for sustainability measures to be implemented and have the execution details retouched to improve the adoption procedure for greater case studies [1,3].**

The main research objectives were to evaluate the environmental impacts and road traffic performance of promoting the use of carpooling. More specifically, to provide an evaluation of carpooling adoption under pandemic circumstances by considering the health safety recommendations. The case studies were the 3 campuses of the University of Aveiro: 1) Campus Universitário de Santiago; 2) Águeda School of Technology and Management; and 3) Aveiro North School.

The framework concept is based on a microsimulation approach to evaluate vehicular pollutants emissions and traffic performance with high temporal precision. The framework started with the development of monitoring campaigns to collect road traffic volumes, the vehicle average occupancy ratio, vehicle dynamics and to develop a site characterization at each case study. The next step was to code the network and to perform the calibration and validation of the microscopic traffic simulation model. Then, the operational scenarios were defined: baseline (corresponding to the current conditions at each case study), and carpooling scenarios. Finally, pollutants emissions and road traffic performance were evaluated. This process was accomplished through an integrated application of VISSIM and the Vehicle Specific Power (VSP) methodology.

At Campus Universitário de Santiago, results indicate that carpooling with groups of up to 3 people commuting to the university campus is able to significantly reduce the CO_2 and NO_X emissions by 5% and 7% networkwide, respectively. Regarding road traffic performance, the average speed significantly increased by 7% and travel time was significantly reduced by 8%. The carpooling scenario was able to reduce the NOx emissions per vehicle per km by near to 7%. The most critical segments regarding pollutants emissions are located near intersections characterized by roundabouts, traffic lights and stop-controlled junctions. These regions accounted for near 20% of CO_2 and NO_X total network emissions in the baseline scenario. The carpooling scenario was able to reduce the impact of such segments regarding CO_2 emissions and NO_X emissions by around 4%.

At the other 2 campuses, a positive outcome was also achieved with the implementation of carpooling although no statistically significant impacts were obtained mainly due to these networks being characterized by lower road traffic congestion levels.

Strategies to implement carpooling under public health threats should contemplate the following points: 1) to set vehicle occupation limits for carpoolers (max. 3 people per vehicle, including driver); 2) vehicle occupants have to follow the health safety recommendations; and 3) carpoolers have access to carpooling dedicated parking spaces. Findings from the present research demonstrate that under this set of constraints and propositions, it is expected that carpooling can have a positive outcome in the general network.

Future work should address the network and campus impacts regarding road safety and noise emissions. Furthermore, a wider analysis of traffic performance parameters should be considered.

Keywords — Carpooling; post-pandemic mobility; pollutants emissions; traffic performance.

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Micro-analysis of a diesel vehicle driving volatility and impacts on emissions for intercity corridors

Elisabete Ferreira [(a)], Paulo Fernandes [(a)], Behnam Bahmankhah[(a)], Margarida C. Coelho[(a)]
(a) - Department of Mechanical Engineering, University of Aveiro
(a) Aveiro, Portugal
(a) – elisabetedsf@ua.pt

***Abstract* — An in-depth understanding of driver behavior is an important step to improve road safety and environmental performance. The number of fatalities is still far from EU target of 15,750 fatalities for 2020 [1]. Also, road transport represents more than 70% of the transport-related greenhouse gas emissions, and is a relevant contributor of pollution as means of nitrogen oxides (NOx) and particulate matter (PM) emissions [2].Volatility can be defined as the extent of variations in driving, which can be characterized by accelerations/braking, lane change and unusual high speed for roadways conditions. However, there is a lack of knowledge, in what concerns analyzing driver's volatility and its relationship with exhaust emissions and how it can be used as safety eco-indicator [3]. This work investigates a driving volatility concept for assessing emissions and driving behavior classification. To this end, an empirical approach that combined vehicle activity and emission rates for light duty vehicles was exploited. Field measurements were collected from four probe vehicles in one rural, and two highway routes using Portable Emission Measurement Systems (PEMS), Global Positioning System (GPS) receivers and On-board Diagnostic (OBD) scan tool, to measure real-world tailpipe emissions, position and engine activity data. Exploratory analysis using Spearman correlation, Principal Component Analysis (PCA), and then ANOVA was performed. PCA allowed to differentiate using plot visualization different driving behaviors and well-separated between motorways and national road data. Indeed, retaining only the first two principal components, more than 99% of total variability was explained. Hence, it was found that RPM, speed and altitude were the most contribute variables explaining the variability in all the data sets. From the results of ANOVA, we concluded that there are indeed significant differences between vehicles for acceleration and jerk. Therefore, these variables were used for the classification of driving behavior. Acceleration-based parameters such as relative positive acceleration (RPA) and mean of positive acceleration (MPA), acceleration, vehicular jerk, and power demand thresholds were used to detect changes in emissions for different driving styles. It was also found that vehicular jerk impacted carbon dioxide (CO2) and nitrogen oxides (NOX) per unit distance regardless of driving style or route, especially from negative to null jerk values and during positive accelerations.**

Keywords — Driving Volatility; tailpipe emissions; vehicular jerk

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A Life Cycle Assessment of Shared, Automated and Electric Vehicles

Optimization of a fleet mobility system applied at a regional case study

Mariana Vilaça [(a)], Gonçalo Santos [(b)], Mónica S.A. Oliveira [(a)], Gonçalo Correia [(c)], Margarida C. Coelho [(a)]*

*(a) - Dept. of Mechanical Engineering; University of Aveiro, Centre for Mechanical Technology and Automation (TEMA); (b) - dept. of Civil Engineering; University of Coimbra; Research Centre for territory, transport and environment (*CITTA*) (c) - dept. of Transport & Planning; Delft University of Technology*

(a) Aveiro, Portugal; (b) Coimbra, Portugal; (c) Delft, The Netherlands
mvilaca@ua.pt; gdsantos@uc.pt; monica.oliveira@ua.pt; g.correia@tudelft.nl; margarida.coelho@ua.pt

***Abstract* — To particularly face mobility's environmental impacts and consider the remaining sustainability pillars (economic and social), the transport sector goes through some significant transformations –automation, electrification, and shared mobility [1]. The existing literature on energy implications of these emerging technologies is focused on operational impact, and little is known about the full life cycle impact [2]. This work presents a holistic approach that combines a life cycle assessment of a shared automated and electric vehicle (SAEV) service, considering different vehicle fleet sizes and electricity generation scenarios. A flow-based optimization approach was developed to assess the SAEV fleet size and vehicle kilometers traveled for one passenger and four passenger's vehicle capacity based on the Aveiro region's one-year travel demand. The life cycle impact assessment of the SAEVs system was modeled on Simapro [3] considering the impact categories: global warming potential, stratospheric ozone depletion, tropospheric ozone formation, fine particulate formation, and terrestrial acidification were evaluated. These impacts were analyzed based on their potential to damage human health and as indicators of potential ecosystems' effects.**

According to the results, a reduction of 58% of all analyzed impact categories is verified for the implementation of SAEV service comprised by vehicles with capacity for four passengers. The use stage, particularly its energy consumption, is the main contributor to environmental impacts. Thus, the incorporation of electricity generated by renewable sources (namely, wind and photovoltaic power systems) has great potential to reduce mobility systems' overall environmental life cycle assessment impacts. This analysis points to opportunities to improve mobility systems' environmental and energy performance with the usage of regional SAEVs. This application also highlights the importance of considering future mobility systems more inclusive and accessible.

Keywords*— *Shared Automated and Electric Vehicles; Life Cycle Assessment; Environmental Impacts, Regional Mobility.

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Platooning optimization with mixed vehicle arrangements based on performance and environmental indicators

Micael Rebelo [(a,b)], Sandra Rafael [(a)], Jorge Bandeira [(b)]
(a) - CESAM & Dept. Environment and Planning, University of Aveiro; (b) Centre for Mechanical Technology and Automation, Dept. Mechanical Engineering, University of Aveiro
(a) Aveiro, Portugal
(a) – {micaelrebelo; sandra.rafael; jorgebandeira}@ua.pt

***Abstract* — In the future, connected systems need to work together to achieve sustainable mobility. This work aims to optimize platooning formations that encompass light and heavy-duty vehicles that travel the highways. This optimization will be based on road externalities, including environmental indicators and different platooning characteristics. These platooning characteristics will involve vehicle order in the platoon and the overall speed of the vehicles. Numerical and physical modelling will be used to support the development of an autonomous control system for platoons. The system will be supported by a machine learning technique that will be able to estimate vehicle consumption, traffic emissions and local air quality, at near real-time. In this regard, the "Platune" system will automatically advise the formation of platoons with specific data (order, speed and number of vehicles) to minimizing road traffic externalities.**

Transport systems connect people, cultures, cities, countries and continents. Intercity mobility is vital to the economic development of cities by promoting accessibility for goods and commuters. At the same time, transport systems generate negative external effects [1]. The transport sector is a major contributor to greenhouse gas (GHG) emissions and the main source of air pollution. Within the transport sector, road transport accounts for 35% of nitrogen oxides (NOx) emissions [2], making it the most contributing mean of transport. Air pollutants resulting from the transport sector produce substantial environmental challenges and environmental costs due to air pollution and climate change. Transport is also responsible for congestion, road capacity bottlenecks, accidents and noise [3, 4]. One solution to these transport problems is platooning. Platooning is a group of vehicles that drive close together, acting as one, with the advantage of reducing the fuel consumption of the convoy. This work will explain how these systems can be connected to provide the creation of smart highways systems that can manage their traffic to reduce road traffic externalities, including air pollution and climate change. For that, the impact of different platoons on the drag coefficient and its related impact on the atmospheric emissions was firstly investigated. Preliminary tests showed that the introduction of platoons in highways lead to a decrease of 3% on NOx emissions. Future work will explore the impact of road slope, acceleration and speed values, in conjunction with the drag coefficient to develop and optimize the "Platune" system.

Keywords — Air quality; Fuel economy; Machine Learning; Physical and Numerical modelling; Platooning.

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Decision support system for accessing costs and risks of connected and autonomous vehicles as mobility service in urban contexts

Mónica Rodrigues [(a)], Maria Conceição Costa [(b)] Jorge Bandeira [(a)],
(a) - Department of Mechanical Engineering, Centre for Mechanical Technology and Automation, University of Aveiro; (b) - Department of Mathematics, Center for Research & Development in Mathematics and Applications, University of Aveiro
(a) Aveiro, Portugal; (b) – Aveiro, Portugal
(a) – monica.joana@ua.pt; jorgebandeira@ua.pt; (b) – lopescosta@ua.pt

***Abstract* — A predicted increase of connected autonomous vehicles (CAVs) in our roads paved the way for new opportunities and challenges towards the promotion of sustainable mobility. However, the impacts of CAVs on the road environment and its implications are widely dependent on technological choices and public policy [1,2].**

Therefore, this research (PhD Workplan) intends to assess whether CAVs could be effective mobility solutions for improving social, economic and environmental efficiency [3]. This question will be addressed by developing a decision support tool driven by comprehensive data analysis and modelling processes. The outputs achieved will integrate a tool that will support transport systems' planning and the implementation of urban strategies to introduce CAVs [4,5].

Thus, the research's main focus encompasses the development of a model-driven decision support system (DSS) that allows assessing the costs and risks of implementing CAVs in urban contexts [3,4]. Three specific research objectives are assumed: I) Predicting impacts of CAVs operation in urban contexts, by analysing cost-efficiency, transportation demand and mobility patterns considering market penetration scenarios of CAVs in Portugal; II) Conceiving a hybrid transport planning tool to assess possible restrictions to CAVs on different types of links through field data testing and simulating scenarios using a microscopic traffic model. Data will support the development of a macroscopic model for a full network assessment performance; III) Developing a multidimensional decision tool directed to a wide range of stakeholders, both from public or private sectors, to compute the benefits, costs, constraints and risks of implementing CAVs on urban mobility systems.

Preliminary results from different urban arterials indicate that CAVS can have negative or negligible impacts in some urban contexts. However, if the impact on the traffic flow's energy performance is considered into the internal car following algorithm, using VISSIM software, global energy savings of up to 12% can be achieved.

Keywords* — *Future Mobility; Mobility Planning; Predictive modelling; Risk Analysis for CAVs.

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TEMA – Centro de Tecnologia Mecânica e Automação
Departamento de Engenharia Mecânica
Universidade de Aveiro
Campus Universitário de Santiago
3810-193 Aveiro

Tel: (+351) 234 370 830
Fax: (+351) 234 370 953
e-mail: tema@ua.pt
Website: http://www.ua.pt/tema/

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