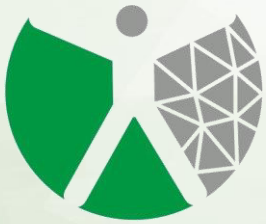

TEchMA2024

7TH INTERNATIONAL CONFERENCE ON TECHNOLOGIES FOR THE WELLBEING AND SUSTAINABLE MANUFACTURING SOLUTIONS

AVEIRO, 6 AND 7TH OF JUNE 2024

tema centre for mechanical technology and automation | dem universidade de aveiro department of mechanical engineering
LASI
FCT Fundação para a Ciência e a Tecnologia

TEMA - Centre for Mechanical Technology and Automation

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

Drawing upon its wealth of human capital and robust capabilities, the Centre for Mechanical Technology and Automation (TEMA) is steadfastly dedicated to fostering sustainable industry practices and enhancing societal well-being. This commitment is underpinned by a relentless pursuit of excellence, characterized by pioneering research and innovation in engineering and technology. TEMA's researchers, in conjunction with the strategic mobilization of projects, play a crucial role in achieving this vision.

Our mission is to develop and provide research competencies that can be applied to the technological needs of society.

TEMA focuses its efforts on three primary mobilization projects (MPs) that are aligned with current societal needs and future global demands. These projects are carried out by a single multidisciplinary research group:

MP 1 – Sustainable Manufacturing Solutions: This initiative centers on advancing manufacturing engineering and technologies to drive industrial innovation. Its objectives include bolstering productivity, elevating product quality, and minimizing waste in production processes.

MP 2 - Technologies for Wellbeing: With a focus on human-centric engineering systems, MP 2 endeavors to enhance societal quality of life by addressing pressing needs and challenges.

MP 3 - Research Infrastructure Services: This project is dedicated to the efficient management and utilization of TEMA's extensive material and human resources, including its 19 laboratories and diverse scientific equipment. The aim is to transform the research infrastructure into an inclusive "open facility" accessible to various stakeholders, including academia, research, and industry.

TEMA's impactful contributions to addressing societal challenges are underscored by its research and development endeavors, which encompass:

Pioneering new products utilizing both traditional and nanoengineering methodologies.

Developing computational and experimental tools to optimize quality, minimize costs, and preserve resources.

Spearheading the development and optimization of technologies to enhance energy efficiency and production scheduling.

Comprising a cohesive unit of researchers with expertise spanning applied mechanics, modelling and simulation, nanoengineering, biomechanics, transportation technologies, applied energy and transdisciplinary domains, TEMA is attuned to global priorities such as equality, gender balance, diversity, and scientific and technological excellence.

Over the past six years, TEMA researchers have made substantial contributions, evidenced by the publication of 1327 papers in internationally peer-reviewed journals indexed by Scopus. Moreover, TEMA has played a pivotal role in training over 600 Master's and supervising 80 PhD students, and its researchers have delivered more than 100 keynote lectures at national and international forums.

Due to its vast knowledge and cooperative culture TEMA is equipped to tackle scientific and technological projects of medium to high complexity, characterized by multidisciplinary attributes. Collaboration with national and international industrial partners accounts for nearly 50% of TEMA's research activities. Furthermore, TEMA is an integral part of the National Roadmap of Research Infrastructures of Strategic Relevance and the European Union Map of Institutions strategic for the development of Key Enabling Technologies.

TEMA's governance structure comprises the Board of Directors, the Scientific Council, the External Scientific and Industrial Advisory Board, and the General Assembly. The Scientific Council, comprising all integrated PhD members, plays a pivotal role in decision-making, while the External Scientific and Industrial Advisory Board comprises three distinguished external academic and industrial figures responsible for providing real-time assessment, guidance, and ensuring alignment with TEMA's overarching mission.

Aveiro, May 14th, 2024
The Director,
António Bastos Pereira

TEchMA2024

Title:
TEchMA2024 – 7th International Conference on Technologies for the Wellbeing and Sustainable Manufacturing Solutions: Book of abstracts

Editors:
António Pereira, Paula Marques, Margarida Coelho, António Completo, Fernando Neto.

Scientific Committee:
Fábio Fernandes, Ana Horovistiz, João Dias Oliveira, António Gil de Campos, Joana Mesquita-Guimarães, Isabel Duarte, Vitor Neto, Stanley Ofoegbu, Gabriela Vincze, Marilena Butuc, André Girão, Ângela Semitela, Aliaksandr Shaula, Olena Okhay, Igor Bdikin, João Dias, Tiago Silva, Fernando Neto, Margarida Coelho, Nelson Martins, Eloísa Macedo, Sérgio Tavares, José Paulo Santos, Jorge Ferreira, Laura Holz, Nathalia Barroca, André Quintã, Pedro Prates, Francisco Loureiro, Jorge Bandeira, Paulo Fernandes.

Program Committee:
Ana Horovistiz, Ângela Semitela, Joana Mesquita-Guimarães, Luciana Rocha, Luís Pereira, Raul Simões.

Publisher:
UA Editora, Universidade de Aveiro.

1st Edition – June 2024

ISBN: 978-972-789-919-7

DOI: https://doi.org/10.48528/mehv-z227

This book is supported by the projects:
UIDB/00481/2020 and UIDP/00481/2020 - FCT - Fundação para a Ciência e a Tecnologia; and Project “Agenda ILLIANCE”; and Projet“AM2R – Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas”; and Project “Agenda ATE”, financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

Intelligent Systems Associate Laboratory

Fundação para a Ciência e a Tecnologia

PRR Plano de Recuperação e Resiliência

REPÚBLICA PORTUGUESA

Financiado pela União Europeia NextGenerationEU

TEchMA2024

7th International Conference on Technologies for the Wellbeing and Sustainable Manufacturing Solutions

Book of abstracts

Content

Program

Thursday, June 6th ROOM - Auditorium 22.3.2

Rception to Participants			**9:00**
Opening Cerrimony			**9:30**
SESSION I: Manufacturing Processes & Simulation	CHAIRS: Ana Horovistiz & Joana Guimarães	Guilherme J. Antunes e Sousa	9:45
		Jorge Santos	10:00
		Tomáš Filá	10:15
		Telmo Fernandes	10:30
		Pedro Fonseca	10:45
Coffee Break			**11:00**
SESSION III: Multiscale Technologies and Devices for Medicine, Environment and Energy	CHAIRS: Ângela Semitela & André Girão	Duarte Almeida	11:30
		Laura Holz	11:45
		Nathalie Barroca	12:00
		Vanessa Graça	12:15
		Lara F. Almeida Paiva	12:30
Lunch Time			**12:45**
SESSION V: Digital transformation	CHAIRS: Jorge Ferreira & José Paulo Santos	Ana Luís Sousa	14:15
		Nuno Sousa	14:45
		Sara Mota	15:00
		Tiago Gândara	15:15
		Diogo Torres	15:30
		Helena Tavares	15:45
Coffee Break			**16:00**
SESSION VII: Manufacturing Processes & Simulation	CHAIRS: Marilena Butuc & Gabriela Vinzce	Mafalda Gonçalves	16:30
		Gabriela Madureira	16:45
		Miguel Vieira	17:00
		Sofia B. Rocha	17:15
		João Pereira	17:30
		Eyuel Lemma	17:45
Closing Session			**18:00**

Thursday, June 6th ROOM - Auditorium 22.3.21

SESSION II: Innovative technologies for Smart Cities	CHAIRS: Eloísa Macedo & Margarida Coelho	Gabriela Garcia	9:45
		Diana Silva	10:00
		Sílvia Soares	10:15
		Fabiana Silva	10:30
Coffee Break			**11:00**
SESSION IV: Predictive algorithms Machine learning Artificial Intelligence	CHAIRS: Gil Andrade & Pedro Prates	Carolina Francisco	11:30
		Pedro Nunes	11:45
		Joaquim M.M. Duarte	12:00
		José Cação	12:15
		Natacha Rosa	12:30
Lunch Time			**12:45**
SESSION VI: Multiscale Technologies and Devices for Medicine, Environment and Energy	CHAIRS: Laura Holz & Natalia Barroca	Alexandra Silva	14:15
		Luís M. Pereira	14:30
		J.R. Ravindran	14:45
		Luís Nascimento	15:00
		João F. Gil	15:15
		André Girão	15:30
		Carlos M. R. Almeida	15:45
Coffee Break			**16:00**
SESSION VIII: Manufacturing for Circular Economy	CHAIRS: Stanley Ofoegbu & Vitor Neto	Mafalda Melo	16:30
		Bogoslav Bašić	16:45
		Tatiana Zhiltsova	17:00
		Tiago Gomes	17:15
Closing Session			**17:30**

Friday, June 7th ROOM - Auditorium José Grácio

Opening Session			**9:25**
SESSION IX: Nanoengineering & Bio-inspired Manufacturing	CHAIRS: Igor Bdikin &	Catarina Lei	9:30
		Luís Nascimento	9:45
		Raul Simões	10:00
		Gabriel Marques	10:15
Multiscale Technologies and Devices for Medicine, Environment and Energy	João Dias	Ângela Semitela	10:30
Coffee Break			**10:45**
SESSION XI: Multiscale Technologies and Devices for Medicine, Environment and Energy	CHAIRS: Francisco Loureiro & Laura Holz	Catarina de Lemos	11:00
		Alfredo S.B. Luemba	11:15
		D. Pukazhselvan	11:30
		Joana R. Pinto	11:45
		João Pedro Santos Almeida	12:00
Lunch Time			**12:15**
SESSION XIII: Innovative Technologies for Smart Cities	CHAIRS: Jorge Bandeira & Paulo Jorge Teixeira Fernandes	Elisabete Ferreira	14:30
		David Figueiredo	14:45
		Tiago C. Pereira	15:00
		Andreia Martins	15:15
		Ana Viriato	15:30
Coffee Break			**15:45**
Closing Ceromiy			**16:15**

Friday, June 7th ROOM - 22.3.2.

Opening Session			**9:25**
SESSION X: Identification systems Predictive algorithms	CHAIRS:: João Oliveira & André Quintã	Jorge Ribeiro	9:30
		Ronaldo Ferreira	9:45
		João Silva	10:00
		Syed Tahir Ali Shah	10:15
		João Marques	10:30
Coffee Break			**10:45**
SESSION XII: Manufacturing Processes & Simulation	CHAIRS: Ana Horovistiz & Fábio Fernandes	Sathishkumar Duraisamy	11:00
		Diogo Teixeira	11:15
		João Ferreira	11:30
		Mehran Ghasempour-Mouizraji	11:45
		Yiyun Wu	12:00
		Miguel Moreira	12:15
		António Festas	12:30
Lunch Time			**12:45**

Sessions and Topics

Session	Topics	Day/Place
I	**1. Sustainable Manufacturing Solutions** a. Manufacturing processes & Simulation	**Thursday, 6th of June** ROOM - 22.3.2 Auditorium
II	**2. Technologies for the Wellbeing** b. Innovative technologies for Smart Cities	**Thursday, 6th of June** ROOM - 22.3.21 Auditorium
III	**2. Technologies for the Wellbeing** a. Multiscale technologies and devices for medicine, environment and energy	**Thursday, 6th of June** ROOM - 22.3.2 Auditorium
IV	**3. Intelligent Systems** a. Identification systems; b. Digital transformation; c. Predictive algorithms	**Thursday, 6th of June** ROOM - 22.3.21 Auditorium
V	**3. Intelligent Systems** b. Digital transformation	**Thursday, 6th of June** ROOM - 22.3.2 Auditorium
VI	**2. Technologies for the Wellbeing** a. Multiscale technologies and devices for medicine, environment and energy	**Thursday, 6th of June** ROOM - 22.3.21 Auditorium
VII	**1. Sustainable Manufacturing Solutions** a. Manufacturing processes & Simulation	**Thursday, 6th of June** ROOM - 22.3.2 Auditorium
VIII	**1. Sustainable Manufacturing Solutions** c. Manufacturing for Circular Economy	**Thursday, 6th of June** ROOM - 22.3.21 Auditorium
IX	**1. Sustainable Manufacturing Solutions** a. Manufacturing processes & Simulation **2. Technologies for the Wellbeing** a. Multiscale technologies and devices for medicine, environment and energy	**Friday, 7th of June** ROOM - José Grácio Auditorium
X	**3. Intelligent Systems** c. Predictive algorithms; d. Machine learning; e. Artificial Intelligence	**Friday, 7th of June** ROOM - 22.3.2 Auditorium
XI	**2. Technologies for the Wellbeing** a. Multiscale technologies and devices for medicine, environment and energy	**Friday, 7th of June** ROOM - José Grácio Auditorium
XII	**1. Sustainable Manufacturing Solutions** a. Manufacturing processes & Simulation	**Friday, 7th of June** ROOM - 22.3.2 Auditorium
XIII	**2. Technologies for the Wellbeing** b. Innovative technologies for Smart Cities	**Friday, 7th of June** ROOM - José Grácio Auditorium

SUSTAINABLE MANUFACTURING SOLUTIONS

Experimental analysis of heterogeneous mechanical tests for sheet metals

Mafalda Gonçalves [(a)], Sandrine Thuillier [(b)] and António Andrade-Campos [(a)]
(a) – Department of Mechanical Engineering, Centre for Mechanical Technology and Automation (TEMA), LASI, University of Aveiro; (b) – Univ. Bretagne Sud, UMR CNRS, IRDL;
(a) Campus Universitário de Santiago, 3810-193 Aveiro, Portugal; (b) – F-56100 Lorient, France
(a) – mafalda.goncalves@ua.pt, (b) – sandrine.thuillier@univ-ubs.fr, (c) – gilac@ua.pt

***Abstract*— The virtual analysis of sheet metal forming processes requires a numerical model that accurately describes the material behavior. For its characterization, several alternatives to the quasi-homogeneous mechanical tests are under study. Unlike these tests, which typically focus on a single strain state, heterogeneous tests offer a wider range of strain states within a single experiment. A larger quantity and quality of mechanical information can be extracted and, therefore, their potential needs to be investigated. This work aims to analyze experimentally the ability of heterogeneous mechanical tests to provide crucial information for sheet metal behavior characterization. Three advanced mechanical tests, named Notched [1], D [2] and TopOpt [3], are submitted to uniaxial loading using advanced high-strength steels. The full-field information is extracted from the specimens' surface using Digital Image Correlation (DIC). The TopOpt specimen has the particularity of having an out-of-plane behavior during the test. Therefore, two stereo DIC systems are used to extract the information from both surfaces. For each test, the complexity of the experimental procedure is analyzed as well as the richness of the mechanical fields using a strain-based mechanical indicator. The results demonstrate that a single heterogeneous test yields a greater quantity and quality of mechanical information compared to multiple quasi-homogeneous tests. The use of multi-DIC systems to measure the out-of-plane displacement of the TopOpt specimen increases the information provided by the test. Heterogeneous tests have the potential to be valuable tools for characterizing sheet metal behavior. Their ability to provide a wealth of mechanical information within a single experiment holds the premise for advancing the accuracy and efficiency of model calibration procedures and consequently of process digitalization.**

Keywords*— *Heterogeneous tests; Experimental analysis; Digital Image Correlation; Sheet metal.

ACKNOWLEDGMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020. This work has also received funding from the Research Fund for Coal and Steel under the grant agreement No. 888153. M. Gonçalves is grateful to the FCT for the Ph.D. grant Ref. UI/BD/151257/2021 and to the ESAFORM association for the mobility grant.

DISCLAIMER

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

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] M. Rossi, F. Pierron, M. Štamborská, "Application of the virtual fields method to large strain anisotropic plasticity", Int. J. Solids. Struct., vol. 97-98, pp. 322–335, 2016.

[2] E.M.C. Jones, J.D. Carroll, K.N. Karlson, S.L.B. Kramer, R.B. Lehoucq, P.L. Reu et al, "Parameter covariance and non-uniqueness in material model calibration using the Virtual Fields Method", Comput. Mater. Sci., vol. 152, pp. 268-290, 2018.

[3] M. Gonçalves, M.G. Oliveira, S. Thuillier, A. Andrade-Campos, "Key performance indicators for heterogeneous mechanical tests", Int. J. Mech. Sci., vol. 264, pp. 108821, 2024.

Design meets complex engineering systems

Focusing on the development of power substations

Gabriela Madureira [(a,b)], Sérgio Tavares [(b)] , Sílvia Soares [(a)] , João Dias-de-Oliveira[(b)]
(a) - ID+ – DeCA; (b) - TEMA – DEM; University of Aveiro, Portugal
(a) gabrielamadureira@ua.pt

***Abstract* — This communication explores the role of holistic design in the development of products and complex engineering systems, with a particular emphasis on enhancing the efficiency and sustainability of electrical substations, an essential part of the power grid. Within the current global landscape there is an urge for a sustainable energy transition** [1]**, characterized by the expansion and interconnection of renewable energy networks on an international scale** [2]**. Consequently, the need arises to not only expand existing infrastructures but also to rehabilitate and innovate by establishing new substations** [3]**. To achieve this, it is necessary to consider various limitations to these implementations, such as ecological sustainability** [4]**, social acceptance** [5]**, and wellbeing issues** [6]**. The primary objective of this research is twofold: firstly, to conduct a comprehensive literature review encompassing the realms of engineering and design as applied to electrical substations; and, secondly, to compile insights from projects across diverse disciplines, all of which are intertwined with the development of complex engineering systems. These projects, irrespective of their origin, have integrated fundamental principles of product design, such as human-centered and nature-centered design philosophies. This state-of-the-art analysis produced detailed graphs that offer a thorough examination of the current state of electrical substations, considering natural, artificial, and human factors. The findings indicate that although current engineering designs for substations show some environmental awareness, they are still mainly focused on artificial elements, with even less attention to human experience and well-being. This leads to the conclusion that renewable energy substation's design is not fully sustainable. These conclusions were drawn through both quantitative and qualitative analysis of project methodologies. Data analysis and visualization tools were used to create visual summaries, highlighting trends and gaps. This research targets the engineering and product design community, particularly those involved in developing complex systems within varied social and environmental settings. The goal is to enhance the integration of design in electrical substations, leading to more efficient and truly sustainable solutions, and advancing the field of engineering design and energy systems.**

Keywords — Product design; Engineering design; Interdisciplinarity; Electrical substations; Complex systems; Sustainability

ACKNOWLEGEMENTS

This work is funded by the Recovery and Resilience Plan (PRR) and by European Funds NextGeneration EU under the Project "AET – Alliance for Energy Transition", nr. C644914747-00000023, investment project nr. 56, of the Incentive System "Agendas for Business Innovation" with the application 08/2024/BI/AgendasPRR and through the FCT – Fundação para a Ciência e a Tecnologia, I.P. and, when eligible, by COMPETE 2020 FEDER funds, under the Scientific Employment Stimulus – Individual Call (CEEC Individual) – CEECIND/04748/2017/CP1459/CT0048, and under the scope of the projects UIDB/04057/2020, UIDB/00481/2020 and UIDP/00481/2020, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] European Commission, "Communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions," Grids, missing link - An EU Action Plan Grids, vol. COM(2023), p. 22, 2023.

[2] G. Escribano, C. González-Enríquez, L. Lázaro-Touza, and J. Paredes-Gázquez, "An energy union without interconnections? Public acceptance of cross-border interconnectors in four European countries," Energy, vol. 266, no. 126385, p. 16, 2023.

[3] D. Bilobran, "The new industrial revolution: finding life for the buildings left behind," in Acta Polytechnica CTU Proceedings, 2022, pp. 522–526.

[4] E. Turmina, M. R. Kanieski, L. A. de Jesus, L. H. da Rosa, L. G. Batista, and A. N. de Almeida, "Avaliação de impactos ambientais gerados na implantação e operação de subestação de energia elétrica: um estudo de caso em Palhoça, SC," Rev. Ciências Agroveterinárias, vol. 17, no. 4, pp. 589–598, 2018.

[5] S. Batel, "Research on the social acceptance of renewable energy technologies: Past, present and future," Energy Res. Soc. Sci., vol. 68, pp. 1–5, 2020.

[6] P. Upham and K. Johansen, "A cognitive mess: Mixed feelings about wind farms on the Danish coast and the emotions of energy infrastructure opposition," Energy Res. Soc. Sci., vol. 66, no. August, p. 10, 2020.

Modular product architecture approaches in different scientific areas

Miguel Vieira [(a)(*)], Sérgio Tavares[(a,b)], Silvina Félix [(c,d)]

(a) - TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro; (b) - LASI - Intelligent Systems Associate Laboratory, Portugal; (c) - School of Design, Management and Production Technologies Northern Aveiro (ESAN); University of Aveiro; (d) - ID+ - Research Institute for Design, Media and Culture; Department of Communication and Art (DeCA), University of Aveiro.

(a,b,d) - Aveiro, Portugal; (c) - Oliveira de Azeméis, Portugal.

(*) - miguel.vieira9@ua.pt

***Abstract*— Product architecture can be defined as a schematic representation of the connections between functions and physical chunks of a product, through a form of interface [1]. It has emerged as a pivotal aspect of product development across various engineering disciplines since the 1960s [2]. Product architecture can be divided into two variants: modular and integral architecture, where modular architecture divides a system into standardized modules that can be joined with a common interface [1]. The use of modular architecture brings several benefits to product development, such as a high level of customization, upgradeability, swapability and standartization [1]. It also facilitates collaborative work between interdisciplinary teams. With the increasing complexity of products, and the introduction of more sensors, electronics and the digitalization with the Internet of Things (IoT), new methodologies are needed to assist in defining product architectures [3]. Traditional methods used in Engineering, such as the Design Structure Matrix (DSM), were complemented with new methodologies, such as Field Effects and Module Interface Graph (MIG) [3,4]. Therefore, new research must be thought of to define new methodologies to address the systems' complexity and multidisciplinarity in the development of product architectures. For this objective, modularity was investigated in different disciplinary areas where it is applied, such as Biology, Design and Architecture [5]. This research focus is on understanding how insights from nature and diverse scientific domains can inform advancements in engineering product development. Through a comprehensive review and analysis, it is investigated the similarities and differences in the modular and integral architectures found in Engineering, Design, and Biology. Notably, it explores the historical evolution and current applications of modularity in each discipline, highlighting key methodologies and case studies. The conducted research will assist in the definition of a symbiosis between modular and integral architecture for the definition of complex energy distribution systems, such as power transformers. Taking into account a more efficient product lifecycle approach. By elucidating the principles and applications of modular architectures across diverse scientific domains, this research aims to catalyze interdisciplinary collaborations through a common simplified language and foster innovation in product development methodologies.**

Keywords*— *Modular, Product Architecture, Product Development, Interdisciplinary

ACKNOWLEDGEMENTS

The authors acknowledge the support of the Mobilizing Agenda for Business Innovation "ATE - Alliance for Energy Transition" reference BI/UI64/11373/2024 with the Center for Mechanical Technology and Automation (TEMA). The authors also acknowledge UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia; and CENTRO-01-0145-FEDER-022083 - Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] Ulrich, K.T., Eppinger, S.D., 2016. Product design and development; Sixth Edition., McGraw-Hill Education, USA.

[2] Corrêa, L. de A., Kubota, F.I., Miguel, P.A.C., 2012. Towards a contribution to modularity concepts and principal domains. Product Management & Development 10, 119–130. https://doi.org/10.4322/pmd.2013.006.

[3] Kuechenhof, J., Berschik, M.C., Beibl, J., Alonso Fernández, I., Otto, K., Krause, D., Isaksson, O., 2023. Incorporating field effect into design of modular product families, in: Proceedings of the Design Society. Cambridge University Press, pp. 2275–2284. https://doi.org/10.1017/pds.2023.228.

[4] Gebhardt, N., Bahns, T., Krause, D., 2014. An example of visually supported design of modular product families, in: Procedia CIRP. Elsevier B.V., pp. 75–80. https://doi.org/10.1016/j.procir.2014.03.162.

[5] Russell, A.L., 2012. Modularity: An Interdisciplinary History of an Ordering Concept. Information & Culture 47, 257–287. https://doi.org/10.7560/ic47301..

Phase change material's 3D printing encapsulation

Development and optimization of phase change materials macroencapsulation processes and systems

Miguel Moreira[(ab)], Tiago Silva[(ab)], João Dias-de-Oliveira[(ab)], Fernando Neto[(ab)], Cláudia Amaral[(ab)]*
(a) – TEMA – Centre for Mechanical technology and Automation, Department of Mechanical Engineering, University of Aveiro, 3810-193, Portugal
(b) – LASI – Intelligent Systems Associate Laboratory, 4800-058 Guimarães, Portugal
(*) – miguelmoreira1@ua.pt

***Abstract*— According to the literature, Phase Change Materials (PCM) have proven to significantly impact the energy efficiency of multiple thermal systems [1], making them an enticing research topic for many academics. Through the vast quantities of latent energy they require to transition from one physical state to another, they can be used as thermal batteries, releasing or absorbing energy to maintain the surrounding temperature constant for longer periods of time. However, it is noticeable in the literature a lack of solutions to incorporate these materials into both academic research solutions and real-world applications [2,3]. Most of the studies that resort to macroencapsulation use manual methods to produce costume PCM macrocapsules, resulting in unreliable and often defective systems. These methods are not adaptable or ergonomic, with limitations on the filling process being troublesome, repetitive, thus increasing human error. This makes them unusable for large-scale production [4]. Furthermore, these errors culminate in unreliable gathered scientific data, but also makes consumer market penetration very scarce, as it is not economically viable to produce these capsules. Recent advancements in the additive manufacturing industry show that it can be a possible solution to overcome major problems in this ineffectiveness in macroencapsulating PCM. In studies such as in Pandis et al. [5], researchers tried to make 3D printed capsules viable to hold PCM. Other studies such as Yang et al. [6] tried a different approach, where PCM directly 3D printing. This work demonstrates an iteration in the development of an innovative process for the macroencapsulation of PCM resorting to additive manufacturing. The aim of this work is to develop processes and systems that enable users to efficiently and repeatably produce an objective design of macroencapsulated PCM, according to the application. The presented developments in the PCM macroencapsulation processes are backed by an experimental campaign and design of experiments (DoE)). Leakage results of the PCM macrocapsules from the experimental trials is shown, using multiple PCM (Chrodatherm53 and Rubitherm SP21KE) and polymers (PETG and TPU).**

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

ACKNOWLEDGEMENTS

This research was supported by FCT (Fundação para a Ciência e a Tecnologia.) grant 2023.00472.BD.

This article was supported by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] M. Nicotra, M. Caldera, P. Leone, F. Zanghirella, Model-based analysis of thermal energy storage for multiple temperature level heat supply, Applied Thermal Engineering 141 (2018) 288–297. https://doi.org/10.1016/J.APPLTHERMALENG.2018.05.132.

[2] T. Silva, R. Vicente, C. Amaral, A. Figueiredo, Thermal performance of a window shutter containing PCM: Numerical validation and experimental analysis, Applied Energy 179 (2016) 64–84. https://doi.org/10.1016/J.APENERGY.2016.06.126.

[3] R.M.S.F. Almeida, R. da S. Vicente, A. Ventura-Gouveia, A. Figueiredo, F. Rebelo, E. Roque, V.M. Ferreira, Experimental and Numerical Simulation of a Radiant Floor System: The Impact of Different Screed Mortars and Floor Finishings, Materials 15 (2022). https://doi.org/10.3390/MA15031015.

[4] M. Moreira, J. Dias-de-Oliveira, C. Amaral, F. Neto, T. Silva, Outline of the incorporation of phase change materials in radiant systems, Journal of Energy Storage 57 (2023). https://doi.org/10.1016/J.EST.2022.106307.

[5] P.K. Pandis, S. Papaioannou, M.K. Koukou, M.G. Vrachopoulos, V.N. Stathopoulos, Differential scanning calorimetry based evaluation of 3D printed PLA for phase change materials encapsulation or as container material of heat storage tanks, Energy Procedia 161 (2019) 429–437. https://doi.org/10.1016/J.EGYPRO.2019.02.088.

[6] Z. Yang, S. Jia, Y. Niu, X. Lv, H. Fu, Y. Zhang, D. Liu, B. Wang, Q. Li, Bean-Pod-Inspired 3D-Printed Phase Change Microlattices for Solar-Thermal Energy Harvesting and Storage, Small 17 (2021). https://doi.org/10.1002/SMLL.202101093.

Analytical study of key parameters on the heat extraction rate of injection moulds

Sofia B. Rocha [(a.b)], Victor Neto[(a,b)], Mónica S. A. Oliveira[(a,b)]*

(a) - Centre for Mechanical Engineering and Automation (TEMA), Mechanical Engineering Department, University of Aveiro; (b) - Intelligent Systems Associate Laboratory (LASI)

(b) Aveiro, Portugal; (b) – Guimarães, Portugal

(*) – sbmarocha@ua.pt

***Abstract*— The study of new tailored temperature control systems (TCS) still lacks new and broader design rules with a compromise between thermal and structural constraints. Consequently, understanding thermal, fluidic and mechanical processes, may lead to the development of new rules for the TCS design. This work intends to establish routes towards this end by studying the TCS thermal design. With this purpose, the different heat exchanges, the overall heat balance and the fluid dynamics involved in the process, were studied to establish the key parameters of the thermal and fluid processes and determine the correlations between them. The thermal design of the TCS is a 3D transient problem, so some simplifications were made to allow a more comprehensive understanding. Firstly, having established that the total heat exchange with the mould boundary is less than 5% of the heat introduced into the mould by the polymer [1], the model considered an adiabatic frontier with its surroundings. The model also considered the mould as a semi-infinite medium; the semi-infinite medium assumes that the solid extends to infinity in all directions but one and that the temperatures inside the medium are unaffected by the changes in the surface conditions. In fact, when considering an injection moulding (IM) tool, it can be concluded that after a few cycles, in zones well-spaced from the parting plane, the mould temperature is stable and is essentially unaffected by the variations in the part temperature. Apart from these assumptions, the heat introduced into the mould by the polymer was calculated according to the sensible heat equation ($Q=m.cp.\Delta T$). As the heat of the polymer is attained through the sensible heat and the mould temperature after a few cycles is considered constant, a steady state condition is assumed. From the analysis of the heat balance it was concluded that two different heat transfer mechanisms, convection (Qconv) and conduction (Qcond), affect the IM process, having a direct impact on cycle time, and in part quality. Hence, to gain a better understanding of the impact of Qconv and Qcond, and to determine the most dominant parameters, a parametric case study was performed, and they were assessed separately. Regarding the heat transfer by convection, it was concluded that an increase in the convective heat transfer coefficient leads to a reduction in the cooling time. As the convective heat transfer coefficient is influenced by the coolant flow rate and the channel diameter, hence, a parametric study was performed to assess the relative impact of these parameters. Overall, it was concluded that smaller diameters improve the convective heat transfer coefficient, as do higher coolant flow rates, but it is relevant to note that increasing the coolant flow rate or reducing the channel diameter will increase the required pumping power and the pressure exerted by the fluid in the channel. In terms of the heat transfer by conduction, it was found that a higher thermal conductivity of the mould material reduces the cooling time, as it increases Qcond. In addition, the channel position (distance between channel centreline and mould wall and distance between each channel) was found to be a key factor as it affects not only Qcond, but also the temperature distribution of the part. Proximity between the channels and between channel and the part, lead to lower cooling times, a fact that has a direct impact on part quality. Moreover, the relation between the distance between channel and part and the distance between channels may lead to non-uniform temperature distributions, to a great extent responsible to part distortion and lack of quality. Furthermore, when comparing Qconv and Qcond, this study has shown that Qconv has a higher impact on the final cooling time. Therefore, when design a TCS special attention must be paid to the coolant flow rate and channel diameter proper selection if cycle time minimization and productivity improvement is being envisioned. Having identified the key parameters for the TCS thermal design, it is now essential to investigate the TCS structural analysis to establish the proper trade-off between part quality, productivity and mould life.**

Keywords*— *injection moulding; temperature control system; thermal analytical model, key parameters, heat extraction.

ACKNOWLEGEMENTS

The authors acknowledge FCT – Fundação para a Ciência e Tecnologia, for the PhD grant ref. 2022.10869.BD (SBR), and the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] B. B. Kanbur, S. Suping, and F. Duan, "Design and optimization of conformal cooling channels for injection molding: a review," International Journal of Advanced Manufacturing Technology, vol. 106, no. 7–8. Springer, pp. 3253–3271, Feb. 01, 2020. doi: 10.1007/s00170-019-04697-9.

Thermochemical surface treatments and coatings applied to gears of bicycle rear hubs

Jorge Santos [(a)], César Cardoso [(b)], Bernardo L. Tavares [(a)], António B. Pereira [(c)], *F. J. Oliveira [(a)]*

(a) – Department of Materials Engineering and Ceramics; University of Aveiro; (b) – Department of Research and Development; Rodi Industries, S.A.; (c) Department of Mechanical Engineering; University of Aveiro.

(a), (b), (c) Aveiro, Portugal;

(a) – jor.fil@ua.pt

***Abstract*— Bicycle rear hubs are essential components for the transmission of movement from the pedal to the wheel. Gears are one of the main components of bicycle hubs which experience fatigue and wear during service life. Typically, carburized, and hardened steels with or without a coating are used in gears for wear and fatigue resistance [1]. The carburized and hardened steels are used in gears when high case hardness and strength, compressive residual stresses and a tough core are required [2]. Some distortion can occur during carburizing and hardening for complex gear shapes or thin sections which may require a finishing step that can present manufacturing problems. To avoid distortion, nitriding is used in gears when geometry and tolerances cannot be maintained with other thermochemical surface treatments. Typically, nitride hard layers achieve lower depth compared to the hardened layers obtained by carburizing which is disadvantageous to withstand loads for some applications [2]. The electrodeposition of a hard and corrosion resistant chromium coating on gears surface is used to decrease the friction coefficient and enhance corrosion resistance. There are indications that hard chromium coatings decrease the fatigue properties [1,3] and, for this reason, shot peening and the deposition of interlayers has been studied to mitigate the detrimental effect of chromium plating on fatigue properties [4]. Another problem associated to hard chromium coatings is that they are frequently deposited from solutions containing hexavalent chromium (Cr VI) which present environmental issues [5]. The purpose of this study is to compare a benchmark chromium coated steel gear of bicycle rear hubs with a more environmentally friendly alternative steel gears with different nitriding thermochemical surface treatments. Vickers microhardness, microstructural analysis by optical and scanning electron microscopy and X-ray diffraction were used to study the nitride compound layers and chromium coating of the steel gears. After nitriding, the steel presented a compound layer consisting of a porous ε – Fe2-3N top layer and a γ´ - Fe4N inner layer with a lower hardness compared to the chromium coating layer of the coated steel. Additionally, the Vickers microhardness variation across the steels gears cross-sections showed a higher hardness of the benchmark chromium coated steel gear compared to the steel gears with a nitriding layer used in this study, which suggests that specific nitriding steels with more nitride forming elements should be studied for this application.**

Keywords*— *Surface Hardening; Coatings; Hardness; Nitriding; Microstructure.

ACKNOWLEGEMENTS

This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), financed by national funds through the FCT/MCTES (PIDDAC) and the Centre for Mechanical Technology and Automation (TEMA) through the projects UIDB/00481/2020 and UIDP/00481/2020. This study was also funded by the PRR – Plano de Recuperação e Resiliência and by the NextGenerationEU funds at Universidade de Aveiro, through the scope of the Agenda for Business Innovation "AM2R - Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas" (Project no. 15 with the application C644866475-00000012).

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] T.J. Mackin, N. Anderson, S. Aguilar, G. Beemiller, B. Copsey, D. Draper, E. Eckberg, L. Herbert, D. Layton, Fatigue failure of a star-ratchet gear, Eng Fail Anal 32 (2013) 334–347. https://doi.org/10.1016/j.engfailanal.2013.03.009.

[2] AGMA 2004-B89, Gear Materials and Heat Treatment Manual, Virginia, 1995.

[3] M.J. Ortiz-Mancilla, C. Mariño-Berroterán, J.A. Berríos-Ortiz, G. Mesmacque, E.S. Puchi-Cabrera, Effect of a thin hard chromium coating on fatigue behaviour of 4140 steel, Surface Engineering 20 (2004) 345–352. https://doi.org/10.1179/026708404225020233.

[4] H.J.C. Voorwald, R. Padilha, M.Y.P. Costa, W.L. Pigatin, M.O.H. Cioffi, Effect of electroless nickel interlayer on the fatigue strength of chromium electroplated AISI 4340 steel, Int J Fatigue 29 (2007) 695–704. https://doi.org/10.1016/j.ijfatigue.2006.07.004.

[5] ECHA - European Chemical Agency, Chromium (VI). https://echa.europa.eu/pt/substance-information/-/substanceinfo/100.132.559 (accessed 28 February 2024), 2022.

The Impact of Density on the Dynamic Mechanical Behaviour of Cork Agglomerates via Experimental and Numerical Methods

G. J. Antunes e Sousa [(a) (b)], A. J. C. Silva [(a) (b)] (b) , G. F. Serra [(a) (b)], F. A. O. Fernandes [(a) (b) (c)], R. J. Alves de Sousa [(a) (b) (c)]

(a) - *Department of Mechanical Engineering (DEM), University of Aveiro (UA), Campus de Santiago, Aveiro, 3810-193, Portugal;*

(b) Centre for Mechanical Technoly and Automation (TEMA), University of Aveiro (UA), Campus de Santiago, Aveiro, 3810-193, Portugal;

(c) Intelligent Systems Associate Laboratory (LASI), University of Minho (UMinho), Campus Azurém, Guimarães, 4800-058, Portugal;

***Abstract*— Cellular materials have been widely used in various technical applications due to their exceptional properties, including reduced density, non-toxicity, low heat conductivity, permeability, high crashworthiness, and fire resistance. This work attempts to determine the relationship between material density and stress relaxation behaviour by modelling the dynamic compressive behaviour of agglomerated cork using finite element analysis. The entire rebound phase and subsequent second impact were further analysed and simulated by incorporating the Mullins effect into the constitutive modelling of impact testing. The mechanical characteristics of three different agglomerated cork composite samples were assessed using quasi-static and dynamic compression tests, which were used to input the numerical model. The findings indicate that agglomerated cork exhibits considerable potential for elastic rebound, particularly at dynamic strain rates when permanent deformation is minimal. For example, the most significant permanent plastic deformation is less than 10%, and the lowest bounce-back energy is 11.8% of the initial kinetic energy. Additionally, by faithfully simulating the material's dynamic compressive behaviour, the material model simulation sufficiently captures the agglomerated cork's reaction to the initial and subsequent hits.**

Keywords*— *Finite element analysis (FEA); Cork agglomerates; Mechanical behaviour; Mullins effect.

ACKNOWLEGEMENTS

The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Projeto n.º46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] I. Alcântara, F. Teixeira-Dias, M. Paulino, "Cork composites for the absorption of impact energy", Composites Structures, vol. 95, pp. 16-27, January 2013.

[2] M. Paulino, F. Teixeira-Dias, "An energy absorption performance indez for cellular materials – development of a side-impact cork padding", International Journal of Crashwothiness, vol. 16, pp. 135-153, April 2011.

[3] L. Gibson, M. Ashby, "Cellular Solids: Structure and Properties" (2nd ed., Cambridge Solid State Science Series), Cambridge: Cambridge University Press, 1997.

[4] D. L. Landro, G. Sala, D. Olivieri, "Deformation mechanisms and energy absorption of polystyre foams for protective helmets", Polymer Testing, vol. 21, pp. 217-228, 2002.

[5] S. Quellet, D. Cronin, M. Worswick, "Compressive response of polymeric foams under quasi-static, medium and high strain rate conditions", Polymer Testing, vol.25, pp. 731-743, September 2006.

[6] F. A. O. Fernandes, R. T. Jardin, A. B. Pereira, R. J. Alves de Sousa, "Comparing the mechanical performance of synthetic and natural cellular materials", Materials & Design, vol. 82, pp. 335-341, October 2015.

[7] M. Ptak, P. Kaczynski, F. A. O. Fernandes, R. J. Alves de Sousa, "Assessing impact velocity and temperature effects on crashwortiness proprerties of cork material", International Journal of Impact Engineering, vol. 106, pp. 238-249, August 2017.

[8] H. Pereira, "Cork: Biology, Production and Uses" (1st ed.), Amsterdam, Elsevier Science, 2007.

[9] G. J. Antunes e Sousa, A. Rocha, F. A. O. Fernandes, R. J. Alves de Sousa, "Shear thickening fluids in cork agglomerates: an exploration of advantages and drawbacks", Sustainability, vol. 15, pp. 6764, April 2023.

[10] S. Sanchez-Saez, E. Barbero, S. K. Garcia-Castillo, I. Ivañez, J. Cirne, "Experimental response of agglomerated cork under multi-impact loads", Materials Letters, vol. 160, pp. 327-330, December 2015.

[11] O. Anjos, C. Rodrigues, J. Morais, H. Pereira, "Effect of density on the compression behaviour of cork", Materials & Design, vol. 53, pp. 1089-1096, January 2014.

[12] P. T. Santos, P. A. A. Marques, A. B. Pereira, R. J. Alves de Sousa, "Agglomerated cork: A way to taylor its mechanical properties", Composites Structures, vol. 178, pp. 277-287, October 2017.

[13] F. A. O. Fernandes, R. J. S. Pascoal, R. J. Alves de Sousa, "Modelling impact response of agglomerated cork", Materials & Design, vol. 58, pp. 499-507, June 2014.

[14] C. Sergi, S. Boria, F. Sarasini, P. Russo, L. Vitiello, E. Barbero, S. Sanchez-Saez, J. Tirillò, "Experimental and finite element analysis of the impact response of agglomerated cork and its intraply hybrid flax/basalt sandwich strcutures", Composite Structures, vol. 272, pp. 1110-1124, September 2021.

[15] C. Sergi, F. Sarasini, P. Russo, L. Vitiello, E. Barbero, S. Sanchez-Saez, J. Tirillò, "Experimental and numerical analysis of the ballistic responde of agglomerated cork and its bio-based sandwich structures", Engineering Failure Analysis, vol. 131, pp. 1040-1059, January 2022.

[16] I. Alcântara, F. Teixeira-Dias, M. Paulino, "Cork composites for the absorption of impact energy". Composite Structures, vol. 95, pp. 16-27, January 2013.

[17] R. M. Hacket, "Strain-Energy Function. In: Hyperelasticity Primer (1st ed., Switzerland), Springer International, 2016.

Induction brazing of copper pipes for the manufacturing of heat pumps

Eyuel Lemma [(a)], João Dias [(a)], António Bastos *[(a)], Pedro Fonseca [(b)], Ana Horovistiz [(a)]*
(a) – TEMA, Department of Mechanical Engineering, University of Aveiro; (b) – Bosch Thermotechnology
Aveiro, Portugal
(a) – eyuel.abate@ua.pt; joaomdias@ua.pt; abastos@ua.pt; horovistiz@ua.pt (b) –
pedro.fonseca@pt.bosch.com

***Abstract*— The increasing utilization of heat pumps across industrial and residential heating and cooling highlights a notable industry trend, driven by continuous technological advancements. In the manufacturing process of heat pumps, metal pipes such as copper, stainless steel, and aluminum are commonly used. Nevertheless, the joining techniques employed in the manufacturing process pose challenges that can lead to defects within the heat pump system. Despite the widespread integration of heat pumps, traditional torch brazing remains the predominant method for joining components in heat pump manufacturing. However, the conventional approach often leads to vulnerable defects, impacting the overall product quality [1]. In response, induction welding has emerged as a promising alternative, particularly lauded for its capacity to facilitate mass production and efficient brazing processes. The process of induction welding has gained popularity among manufacturers due to its numerous advantages over traditional welding methods. Induction heating is a highly efficient method that results in minimal heat-affected zones, lower thermal distortion, and reduced energy consumption [2]. Additionally, it is a clean process that does not produce harmful fumes or gases. Notwithstanding, challenges persist within the induction brazing process, wherein factors such as thermal distortion-induced cracks and inadequate filler metal penetration can impact joint integrity, compromising system durability and sustainability. This reaffirms the need for more research in this area. Some studies have focused on optimizing parameters like heat input and filler metal composition, but there is a lack of comprehensive research on the interaction of multiple parameters and their combined effect on weld quality [3]. Furthermore, a compressive understanding on thermal distortion influenced by various factors such as localized heating, large thermal gradients, cooling rates and process parameter could not be found in literatures, representing a major scientific gap. Understanding the impact of these factors on the material properties and thermal behavior is crucial for predicting and controlling the distortion. Researchers have identified that a critical issue in induction welding is the creation of a homogenous temperature gradient along the component. When the temperature distribution is homogeneous, the tendencies for distortion and crack formation are reduced. Therefore, maintaining a uniform temperature distribution or allowing for slow heating is crucial strategies to mitigate these problems. One of the challenges in induction brazing of copper pipes, associated with temperature distribution is the occurrence of heterogeneous temperature, which can lead to issues such as the flow of filler material out of the gap between the pipes. In cases where the surface temperature is higher, the filler material tends to flow towards the hotter regions, resulting in incomplete capillary formation or porosity. This incomplete filling can lead to leakages in the welded joint. To address this issue, it is essential to maintain a homogeneous temperature distribution during the welding process. In order to address these challenges and optimize the key parameters, numerical modeling will be employed to predict the temperature distribution of the workpiece and validated by experimental analysis. Furthermore, the quality of the welded joints will be evaluated through macro-and microstructural analyses.**

Keywords*— *Induction brazing; copper pipe welding;; welding parameters; welding joint quality; heat pumps.

ACKNOWLEGEMENTS

The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union, and had laboratory support from the Centre for Mechanical Technology and Automation (TEMA), projects UIDB/00481/2020 and UIDP/00481/2020.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] M. Way, J. Willingham, & R. Goodall, "Brazing filler metals", International Materials Reviews, vol. 65, no. 5, p. 257-285, 2019.

[2] P. Zhao, L. Zhao, L.Tan, Z. Xu, L. Wang and X. Zhao, "Investigation on the induction brazing of copper–steel tubes with different coil structures". *Welding in the World*, vol. *65* no.6, pp.1181-1188, 2021.

[3] G. Wang, Y. Yang, P. Wu, D. Shu, D. Zhu, C. Tanet al., "Effect of brazing temperature on microstructure and mechanical properties of tial/zrb2 joint brazed with cutizrni filler", Journal of Manufacturing Processes, vol. 46, p. 170-176, 2019.

Electron Beam Welding for Heat Pump Manufacturing

Sathishkumar Duraisamy [(a)], Ana Horovistiz [(a)], António Bastos *[(a)], Nelson Ferreira [(b)], João Dias [(a)]*
(a) – TEMA, Department of Mechanical Engineering, University of Aveiro; (b) – Bosch Thermotechnology Aveiro, Portugal
(a) – sathishkumard@ua.pt; joaomdias@ua.pt; abastos@ua.pt; horovistiz@ua.pt (b) – nelson.ferreira@pt.bosch.com

***Abstract* – In 2021, households in the European Union (EU) represented 27% of the final energy consumption, with a substantial portion (64.4%) dedicated to residential heating** [1]**. The use of heat pumps is a promising and safe measure to mitigate climate changes, while providing comfort and wellbeing worldwide. Thus, it is expected a significant increase in the production of heat pumps for heating and cooling applications. The manufacturing process of heat pumps and refrigerators involves numerous amounts of welding to connect its components using copper pipes. Nowadays, the welding of these components and copper pipes is mostly carried out through brazing processes. However, conventional brazing methods used in heat pump manufacturing present challenges related to production efficiency, reliability, worker safety, and environmental implications, including energy consumption and greenhouse gas emissions. In heat pump manufacturing, the brazing of pipes can be done in an oven for small, isolated parts, but it is mostly done manually, especially for joining the pipes to the heat exchangers, compressors, and valves, which is prone to the appearance of defects in the joints, consequently leading to product failure.Heat pump systems are subjected to inherent strong vibrations caused by the compressor, as well as temperature shocks that occur whenever the thermodynamic cycle is inverted. These harmful conditions contribute to intensifying any weaknesses or defects in brazed joints, which compromise heat pumps' structural integrity, leading to refrigerant fluid leaks that culminate in system failure. Moreover, these refrigerant fluids are hazardous to the environment and highly flammable, emphasizing the importance of implementing rigorous quality control measures in brazing processes to avoid any possible leaks over time. Electron-beam welding (EBW) is a high-energy density fusion process in which a joint is bombarded with a strongly focused beam of electrons. EBW provides accurate heat input control and avoids undesired microstructures and defects** [2]**. Further research is required to investigate the potential of EBW for joining copper and dissimilar materials for heat-pump manufacturing. Previous studies primarily examined the microstructures, mechanical properties, and welding techniques of different materials using EBW. However, there has been limited exploration of fusion zone microstructures, defects, and mechanical properties of joints welded using EBW. Understanding how the process parameters affect the quality of these joints is critical for investigate the suitable of EBW technologies in heat pump manufacturing, improving the reliability of heat pump systems' production. Despite of EBW potential, further studies are needed to investigate the effect of several process parameters in the welding joints, particularly heat control, in order to overcome the current limitations and enhance the quality and reliability of the heat pump systems. This study aims to improve the welding quality of copper pipes connections by implementing an EBW process. Several EBW process parameters, including welding speed, beam defocus, beam current, and oscillation are studied and calibrated to obtain strong and leak proof connections with excellent penetration and compactness, thereby contributing to the improvement of heat pumps manufacturing processes.**

Keywords: electron beam welding; copper pipes; welding joints; welding parameters; heat pumps; failure analysis.

ACKNOWLEGEMENTS

The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union, and had laboratory support from the Centre for Mechanical Technology and Automation (TEMA), projects UIDB/00481/2020 and UIDP/00481/2020.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] Eurostat, "Energy consumption in households /11zs -- Energy consumption in households, 2008-2020," no. June 2022, pp. 1–10, 2022.

[2] M. Lipińska et al., "Application of electron beam welding technique for joining coarse-grained and ultrafine-grained plates from Al-Mg-Si alloy," J. Manuf. Process., vol. 104, 2023, doi: 10.1016/j.jmapro.2023.08.057.

A new concept of cork-STF composites for impact mitigation

T.R.M. Fernandes [(a)], R.J. Alves de Sousa [(a),(b)], F.A.O. Fernandes [(a),(b)]
(a) – Centre for Mechanical Technology and Automation (TEMA), Department of Mechanical Engineering, University of Aveiro; (b) – LASI – Intelligent Systems Associate Laboratory
(c) Aveiro, Portugal; (b) – Guimarães, Portugal
(a) – telmorfernandes@ua.pt

In recent years, the development of lightweight and high-performance materials for impact mitigation has garnered significant attention across various industries, ranging from aerospace to sports equipment [1-3]. Research has focused on developing innovative composite materials that offer lightweight and flexible features while enhancing impact resistance. Sustainability is also vital, as is shifting from a linear to a circular economy. Natural, lightweight, recyclable, and renewable cork has been used for various things, such as stoppers, flooring, and building insulation [4]. Due to the unusual combination of mechanical, acoustic, and thermal properties found in cork, it has most recently been researched for its possible use in composites for demanding applications. Cork composite structures reinforced with shear thickening fluids (STFs) at the interface have already been studied [5-8]. Although the STF interface positively influences the external force mitigation, this gain is usually marginal. Furthermore, these materials have gained significant attention for their distinctive properties and versatile applications, including defense [9-11]. This work presents a novel concept of cork-STF composite structures, exploring STF containers by varying their depth, area, and shape. Impact tests were performed with a hemispherical impactor reaching an energy of 10 J. These new configurations significantly mitigate the impact force compared with neat samples of agglomerated cork.

Keywords— Cork; STF; Composite; Impact

ACKNOWLEDGMENTS

This work was funded by National Funds by FCT – Fundação para a Ciência e a Tecnologia, I.P., in the scope of the project 2022.04022.PTDC with the following DOI: 10.54499/2022.04022.PTDC (https://doi.org/10.54499/2022.04022.PTDC). This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1]S. Ju Yeo, M. Jun Oh, P. J. Yoo, S. J. Yeo, M. J. Oh, and P. J. Yoo, "Structurally Controlled Cellular Architectures for High-Performance Ultra-Lightweight Materials," *Advanced Materials*, vol. 31, no. 34, p. 1803670, Aug. 2019.

[2] W. Zhang and J. Xu, "Advanced lightweight materials for Automobiles: A review," *Mater Des*, vol. 221, p. 110994, Sep. 2022.

[3] S. Abbasi, M. H. Peerzada, S. Nizamuddin, and N. M. Mubarak, "Functionalized nanomaterials for the aerospace, vehicle, and sports industries," *Handbook of Functionalized Nanomaterials for Industrial Applications*, pp. 795–825, Jan. 2020.

[4] L. Gil, "Cork composites: A review," *Materials*, vol. 2, no. 3. pp. 776–789, 2009.

[5] S. Gürgen, F. A. O. Fernandes, R. J. A. de Sousa, and M. C. Kuşhan, "Development of Eco-friendly Shock-absorbing Cork Composites Enhanced by a Non-Newtonian Fluid," *Applied Composite Materials*, vol. 28, no. 1, pp. 165–179, Feb. 2021.

[6] G. Ferreira Serra, F. A. O. Fernandes, R. J. Alves de Sousa, E. Noronha, and M. Ptak, "New hybrid cork-STF (Shear thickening fluid) polymeric composites to enhance head safety in micro-mobility accidents," *Compos Struct*, vol. 301, Dec. 2022.

[7] L. Oliveira, G. F. Serra, S. Gürgen, R. M. Novais, R. J. A. de Sousa, and F. A. O. Fernandes, "Shear thickening fluids in cork composites for impact mitigation: the role of fumed silica concentration," *Archives of Civil and Mechanical Engineering 2024 24:2*, vol. 24, no. 2, pp. 1–12, Mar. 2024.

[8] M. R. Sheikhi and S. Gürgen, "Deceleration behavior of multi-layer cork composites intercalated with a non-Newtonian material," *Archives of Civil and Mechanical Engineering*, vol. 23, no. 1, pp. 1–11, Mar. 2023.

[9] A. Majumdar, B. S. Butola, and A. Srivastava, "Optimal designing of soft body armour materials using shear thickening fluid," *Mater Des*, vol. 46, pp. 191–198, Apr. 2013.

[10] J. Pernas-Sánchez, J. A. Artero-Guerrero, D. Varas, and F. Teixeira-Dias, "Cork Core Sandwich Plates for Blast Protection," *Applied Sciences 2020, Vol. 10, Page 5180*, vol. 10, no. 15, p. 5180, Jul. 2020.

[11] G. La Fauci, M. Parisi, A. Nanni, L. Crosetta, N. M. Pugno, and M. Colonna, "Design and proof-of-concept of an advanced protective system for the dissipation of tangential impact energy in helmets, based on non-Newtonian fluids," *Smart Mater Struct*, vol. 32, no. 4, Apr. 2023.

Numerical study of the importance of heat transfer during the cooling of steel billets

Diogo Teixeira [(a)], Fernando Neto [(a)], Pedro Prates [(a)]
University of Aveiro
(d) 3810-193 Aveiro, Portugal.
(a) - diogofilipect@ua.pt

***Abstract*—This work was dedicated to the study of finite element modelling and simulation of heat transfer of steel billets in the context of the continuous casting process. This project had the support of SN Maia-Siderurgia Nacional, S.A., a company belonging to the Megasa group. This project involved an analysis of work carried out in the area of modelling and simulation of steel billets, when subjected to heat transfer processes by external means in the mold and spray chamber, with the aim of promoting an understanding and analysis of the process, thus providing concrete information regarding the temperature distribution and solid shell thickness created throughout the entire process, something which is not possible to obtain and observe at an industrial level. This project aimed to improve the perception of the company SN. Maia of the heat transfer events that occur throughout the entire process, the main objective of which is to avoid possible problems in the production of steel billets, avoiding possible cracks and breaks in the billet structure, something that cannot be predicted or avoided at an industrial level. For a more theoretical perception of the continuous casting process, an analysis of in this area was carried out, which made it possible to understand the impact of surrounding factors such as cooling of the billet in the ingot mold and in the spray zone and even the contact of the billet with the surrounding environment (air), which directly affect the cooling of the billet and how these factors accelerate its solidification [1-7]. This project began by defining some critical aspects of the model, such as the boundary conditions, the water heat transfer processes in the ingot mold and in the sprays and the variables to be taken into consideration, which led to a precise and justified selection of the use of the Ansys Fluent Finite Element software [1, 2, 6]. In relation to the results obtained, some parametric studies were carried out, varying some important parameters in the project, such as pouring speed, flow rates and spray pressures for a billet with dimensions 120x120 mm. The objective of all these variations was to obtain a detailed understanding of the process, understanding how the variation in these external conditions also altered the solidification process, with the main objective being to find a balance so that there were no sharp variations in the temperature distribution on the surface and in the core of the billet, promoting the most uniform solidification possible and considerably reducing the possibility of cracks inside the billet. Taking this into account, it was possible to demonstrate that the sprays play a fundamental role in the billet solidification process, ensuring that the temperature inside and outside the billet does not improve and guaranteeing solidification without cracks or ruptures. The project also highlights that the casting speed has fundamental role in the process, so the lower the speed, the faster the billet will be the solidification in the process.**
All results presented in the project aim to promote a better understanding of the phenomena of the continuous casting process, such as cooling in the ingot mold, spray impact and even casting speed, promoting a broader and more accurate understanding of the heat transfer process in the scope of the continuous casting area.

Keywords— Continuous Casting; Steel Billets; Heat Transfer; Spray Chamber; Modelling and Simulation; Finite Elements.

ACKNOWLEGEMENTS

This work was supported by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia; and CENTRO-01-0145-FEDER-022083 – Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

References

[1] Janik, M., & Dyja, H. (2004). Modelling of three-dimensional temperature field inside the mould during continuous casting of steel. Journal of Materials Processing Technology, 157–158(SPEC. ISS.), 177–182. https://doi.org/10.1016/j.jmatprotec.2004.09.026

[2] Maurya, A., & Kumar Jha, P. (2014). EFFECT OF CASTING SPEED ON CONTINUOUS CASTING OF STEEL SLAB. In Ambrish Maurya and Pradeep Kumar Jha. http://ijmerr.com/special-Issue.php

[3] Meng, Y. A., & Thomas, B. G. (n.d.). Heat-Transfer and Solidification Model of Continuous Slab Casting: CON1D.

[4] Ramírez-López, A., Aguilar-López, R., Palomar-Pardavé, M., Romero-Romo, M. A., & Muñoz-Negrón, D. (2010). Simulation of heat transfer in steel billets during continuous casting. International Journal of Minerals, Metallurgy and Materials, 17(4), 403–416. https://doi.org/10.1007/s12613-010-0333-5

[5] Tkadleçková, M., Válek, L., Socha, L., Saternus, M., Pieprzyca, J., Merder, T., Michalek, K., & Kováç, M. (2016). Study of solidification of continuously cast steel round billets using numerical modeling. Archives of Metallurgy and Materials, 61(1), 221–226. https://doi.org/10.1515/amm-2016-0041

[6] E. Laitinen, R. N. & S. L. (1993). Calibration Of The Real-time Heat Transfer Model For The Simulation Of The Continuous Casting Process.

Advanced design of meta-structures through additive manufacturing: A Review

João Ferreira [(a)], Sérgio Tavares [(a)], Victor Neto[(a)]*
(a) TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, 3810 - 193 Aveiro, Portugal
(*) joaolmf@ua.pt

***Abstract*— The convergence of additive manufacturing (AM) and metamaterials can revolutionize various engineering fields due to their unique properties and design flexibility. This review aims to elucidate the role of AM in developing metamaterials, detailing the manipulation of their microstructures and properties.**
The term metamaterial is a composite of 'meta', signifying 'beyond', and 'materials', and these are materials engineered to exhibit properties not found in nature. Metamaterials are created from assemblies of multiple elements made from composite materials, such as metals and polymers. The structural elements of these materials can be arranged in both repeating and non-repeating patterns. Their unique properties come from both their base material's chemical composition and their designed structures. Their precise shape, geometry, size, arrangement, and orientation endow them with advanced properties, enabling them to manipulate, absorb, enhance, and bend waves, ranging from acoustics to electromagnetic waves. This allows them to achieve functionalities that exceed those of conventional materials [1].
AM, also known as 3D printing, enhances the development of metamaterials by enabling the construction of complex geometries, which are otherwise difficult or impossible to fabricate using traditional methods [2, 3]. Advances in AM have facilitated the creation of high-performance metallic alloys and polymers specifically tailored for metamaterials, ensuring their robustness under extreme conditions while preserving structural integrity [4]. However, the AM process also faces challenges, including surface roughness, dimensional accuracy, and the need for optimized support structures [5, 6, 7]. These issues can affect the performance and scalability of 3D-printed metamaterials. Addressing these limitations through interdisciplinary research is essential for further advancements.
This review underscores the transformative potential of additive manufacturing for metamaterials, aiming to advance manufacturing capabilities and develop materials with novel properties.

Keywords*— *Additive Manufacturing, 3D Printing, Metamaterials, Meta-Structures Design, High- Perfomance Polymers, Metal Alloys.

ACKNOWLEGEMENTS

This work is funded by the Recovery and Resilience Plan (PRR) and by European Funds NextGeneration EU under the Project "AET – Alliance for Energy Transition", nr. C644914747-00000023, investment project nr. 56, of the Incentive System "Agendas for Business Innovation" with the application 08/2024/BI/Agendas PRR and through the FCT – Fundação para a Ciência e a Tecnologia, I.P. and, when eligible, by COMPETE 2020 FEDER funds, under the Scientific Employment Stimulus – Individual Call (CEEC Individual) – CEECIND/04748/2017/CP1459/CT0048, and under the scope of the projects UIDB/04057/2020, UIDB/00481/2020 and UIDP/00481/2020, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] J. Patel, 'Meta-materials', International Journal of Scientific Research in Engineering and Management, vol. 06, no. 03, pp. (page numbers if available), Mar. 2022, doi: 10.55041/IJSREM11775.

[2] A. Bandyopadhyay and B. Heer, 'Additive manufacturing of multi-material structures', Materials Science and Engineering: R: Reports, vol. 129, pp. 1–16, Jul. 2018, doi: 10.1016/J.MSER.2018.04.001.

[3] O. Santoliquido, G. Bianchi, and A. Ortona, 'Additive Manufacturing of Complex Ceramic Architectures', Industrializing Additive Manufacturing - Proceedings of Additive Manufacturing in Products and Applications - AMPA2017, pp. 117–123, 2018, doi: 10.1007/978-3-319-66866-6_11.

[4] L. E. Murr et al., 'Metal Fabrication by Additive Manufacturing Using Laser and Electron Beam Melting Technologies', J Mater Sci Technol, vol. 28, no. 1, pp. 1–14, Jan. 2012, doi: 10.1016/S1005-0302(12)60016-4.

[5] S. Lee, B. Rasoolian, D. F. Silva, J. W. Pegues, and N. Shamsaei, 'Surface roughness parameter and modeling for fatigue behavior of additive manufactured parts: A non-destructive data-driven approach', Addit Manuf, vol. 46, p. 102094, Oct. 2021, doi: 10.1016/J.ADDMA.2021.102094.

[6] A. Al-Ahmari, M. Ashfaq, S. H. Mian, and W. Ameen, 'Evaluation of additive manufacturing technologies for dimensional and geometric accuracy', International Journal of Materials and Product Technology, vol. 58, no. 2–3, pp. 129–154, 2019, doi: 10.1504/IJMPT.2019.097665.

[7] G. Allaire and B. Bogosel, 'Optimizing supports for additive manufacturing', Structural and Multidisciplinary Optimization, vol. 58, no. 6, pp. 2493–2515, Dec. 2018, doi: 10.1007/S00158-018-2125-X/FIGURES/22.

Simulation of phase transformation, hardness, and cooling rate in Laser Metal Deposition

Mehran Ghasempour-Mouizraji [(a,b)], Daneil Afonso [(a,b,c)], Ricardo Alves De Sousa [(a,b)]
(a) - TEMA - Centre for Mechanical Technology and Automation, Mechanical Engineering Department, University of Aveiro, Portugal
(b)LASI - Intelligent Systems Associate Laboratory, Guimaraes, Portugal
(c) School of Design, Management and Production Technologies Northern Aveiro, University of Aveiro, Oliveira de Azeméis, Portugal
(a), Aveiro, Portugal; (b) – Guimaraes, Portugal; (c) Oliveira de Azeméis, Portugal
(a) Mehran@ua.pt

***Abstract*— Laser metal deposition (LMD) is an advanced manufacturing technique that utilizes a high-power laser to melt and deposit metallic powders or wires onto a substrate, creating complex three-dimensional structures or adding material to existing components**[1-2]**. LMD finds applications in various industries, including aerospace**[3]**, automotive** [4]**, and medical**[5]**, for prototyping, repair**[6]**, and production of high-performance components. Its versatility, efficiency, and ability to work with a wide range of materials make it a promising technology in modern manufacturing**[7]**. Effectively control mechanical and microstructural properties, predicting hardness, cooling rate, and phase transformation is crucial in this process.**

In this study, Finite Element Simulation is employed to investigate phase transformation, hardness, and cooling rate, with a focus on varying laser power and scanning speed two pivotal processing parameters. Initially, simulations were conducted using Msc Simufact Welding to validate findings against previously implemented research[8] **Subsequently, a new series of simulations incorporating materials with distinct phase transformation properties was carried out. The substrate utilized was SS316H, while the part comprised Press Hardening Steel-Welding (22MnB5-JMP-MPM). The results indicate that hardness values near the substrate exceed those in other sections of the sample. Additionally, the temperature gradient and cooling rate are notably higher near the substrate, owing to its role as a heat sink for temperature distribution.**

Laser Metal Deposition. Phase transformation, Hardness, Cooling rate, Simuafct

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] M. Ghasempour-Mouziraji et al., "Modeling the effect of processing parameters on temperature history in Directed Energy Deposition: an analytical and finite element approach," Rapid Prototyp. J., 2023, doi: 10.1108/RPJ-05-2023-0165.

[2] M. Ghasempour-mouziraji, J. Lagarinhos, and D. Afonso, "A review study on metal powder materials and processing parameters in Laser Metal Deposition," Opt. Laser Technol., vol. 170, no. October 2023, p. 110226, 2024, doi: 10.1016/j.optlastec.2023.110226.

[3] P. S. Gowthaman, S. Jeyakumar, and D. Sarathchandra, "Effect of Heat Input on Microstructure and Mechanical Properties of 316L Stainless Steel Fabricated by Wire Arc Additive Manufacturing," J. Mater. Eng. Perform., no. Ref 13, 2023, doi: 10.1007/s11665-023-08312-7.

[4] A. Segerstark, Laser Metal Deposition using Alloy 718 Powder Influence of Process, vol. 63, no. January. 2017. [Online]. Available: http://www.diva-portal.org/smash/get/diva2:1161118/FULLTEXT02.pdf%0Ahttp://dx.doi.org/10.1016/j.procir.2017.03.073%0Ahttp://dx.doi.org/10.1016/j.matdes.2015.09.148%0Ahttps://doi.org/10.1016/j.matchar.2018.01.015%0Ahttps://doi.org/10.1016/j.jmatprotec.2018

[5] Q. Wu et al., "Obtaining uniform deposition with variable wire feeding direction during wire-feed additive manufacturing," Mater. Manuf. Process., vol. 32, no. 16, pp. 1881–1886, 2017, doi: 10.1080/10426914.2017.1364860.

[6] G. P. Dinda, L. Song, and J. Mazumder, "Fabrication of Ti-6Al-4V scaffolds by direct metal deposition," Metall. Mater. Trans. A Phys. Metall. Mater. Sci., vol. 39, no. 12, pp. 2914–2922, 2008, doi: 10.1007/s11661-008-9634-y.

[7] M. Wang et al., "Microstructure and mechanical properties of Ti-6Al-4V cruciform structure fabricated by coaxial electron beam wire-feed additive manufacturing," J. Alloys Compd., vol. 960, p. 170943, 2023, doi: 10.1016/j.jallcom.2023.170943.

[8] M. Biegler, P. Khazan, and M. Gatzen, "Improvement of Numerical Simulation Model Setup and Manufacturing Laser-Metal- Deposition Components with an advanced Modelling Strategy," Math. Model. Weld Phenom. 12, C. Sommitsch, N. Enzinger, P. Mayr, no. Dic, pp. 1–12, 2019, doi: 10.3217/978-3-85125-615-4-52.

Scrap rate reduction in crankcase manufacturing

Pedro Fonseca [(a)] and Gabriela Vincze[(a,b,c)]

(a) - Department of Mechanical Engineering, University of Aveiro, 3810-193 Aveiro, Portugal; (b) - Centre of Mechanical Technology and Automation (TEMA), University of Aveiro, 3810-193 Aveiro, Portugal; (c) - LASI - Intelligent Systems Associate Laboratory, Portugal

(e) Aveiro, Portugal;

(a) – pedrogil25@ua.pt

***Abstract*— This study aims to refine the production efficiency by identifying key factors that contribute to scrap generation and implementing robust strategies to minimize waste.**

This work is supported by HORSE Aveiro, a company that produces Gearboxes, lower crankcases, and further motoring components.

Several case studies have been used as references and as guides to kickstart and to continue the study, as well as to provide the theoretical foundation to the methodologies used [1] [2] [3] [4].

The component present in this study is the lower crankcase and the processes involved are the machining and component assembly.

The research utilizes a comprehensive approach combining several Lean Manufacturing techniques. The Plan-Do-Check-Act (PDCA) cycle is central to the methodology, enabling continuous process evaluation and improvement. In-depth root cause analysis is conducted using Ishikawa diagrams, which helps in pinpointing specific production flaws. Additionally, the 5 Whys technique is employed to systematically trace and address the origins of efficiency lapses, while Pareto charts are used to prioritize the causes of scrap that significantly impact production lines.

Data collected from the production floors indicated various systemic issues leading to scrap, including equipment malfunctions, operator errors, and suboptimal process parameters. By applying targeted interventions based on the findings from these Lean tools, the study reports a marked reduction in scrap rates, highlighting a decrease in material waste and an improvement in overall manufacturing efficiency.

Additionally, the implementation of refined operational protocols and regular monitoring has led to sustained improvements, contributing to better resource utilization and cost-efficiency. The present work not only provides insights into practical strategies for waste reduction in crankcase manufacturing but also contributes to broader discussions on sustainable practices in industrial production settings.

This work provides insight into simple and effective measures that can be implemented in every manufacturing industry as well as industry 4.0 solutions such as sensing devices and their purpose, and how they can fit into different situations to make the most out of them.

This study underscores the importance of continuous improvement and waste minimization in manufacturing, suggesting that such efforts are essential for enhancing productivity and environmental sustainability. The findings are expected to serve as a valuable resource for similar industries aiming to optimize production processes and reduce environmental footprints.

Keywords — Lean Manufacturing; PDCA; Ishikawa Diagrams; Pareto Analysis; Root Cause Analysis; Scrap Reduction;

ACKNOWLEGEMENTS

The information provide by HORSE Aveiro is gratefully acknowledge. This work is supported by the projects funded by the Fundação para a Ciência e a Tecnologia: 2022.05783.PTDC, DOI 10.54499/2022.05783.PTDC, UIDB/00481/2020 and UIDP/00481/2020 DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

REFERENCES

[1] Ahmed Baha Eddine Aichouni, Faizir Ramlie, and Haslaile Abdullah. Process improvement methodology selection in manufacturing: A literature review perspective. International Journal of Advanced and Applied Sciences, 8(3):12–20, 2021

[2] Yung-Tsan Jou, Riana Magdalena Silitonga, Ming-Chang Lin, Ronald Sukwadi, and Jovian Rivaldo. Application of six sigma methodology in an automotive manufacturing company: A case study. Sustainability, 14(21):14497, 2022.

[3] Uthiyakumar Murugaiah, Samuel Jebaraj Benjamin, M Srikamaladevi Marathamuthu, and Saravanan Muthaiyah. Scrap loss reduction using the 5-whys analysis.International Journal of Quality & Reliability Management, 27(5):527–540, 2010.

[4] Arturo Realyvásquez-Vargas, Karina Cecilia Arredondo-Soto, Teresa CarrilloGutiérrez, and Gustavo Ravelo. Applying the plan-do-check-act (pdca) cycle to reduce the defects in the manufacturing industry. a case study. Applied Sciences, 8(11):2181, 2018.

.

Numerical study for the construction of continuous bending under tension equipment

Catarina Pereira [(a,b)], João Pereira [(a,b,)], Pedro Prates [(a,b,c)], Marilena Butuc [(a,b,c)] and Gabriela Vincze [(a,b,c)]*

(a) - Department of Mechanical Engineering, University of Aveiro; (b) - Centre of Mechanical Technology and Automation (TEMA), University of Aveiro; (c) - LASI - Intelligent Systems Associate Laboratory
(a,b) Aveiro, Portugal; *(c)* Guimarães, Portugal
[*]joaofapereira@ua.pt

***Abstract* — Lightweighting remains a key focus in the transportation sector, driving continuous advancements in advanced materials to enhance the strength, work-hardening capacity, formability, and energy absorption of structural components for vehicles. Research in metal forming aims to optimize material microstructures to increase ductility and energy absorption during crash loading, while simultaneously reducing energy consumption during forming operations. Alongside the development of new alloys, innovative forming processes are being explored to meet these demands.**

One such innovative process is continuous bending under tension (CBT), which leverages the benefits of incremental forming. In CBT, a bending moment is applied to sheet metal under uniaxial tension. As a result, the localised deformation compensates for the necking that would normally occur under pure tension. Recent studies by Knezevic et al. and Korkolis et al. [1,2] have demonstrated that CBT can achieve superior plastic strains compared to traditional forming processes.

The objective of this study is to numerically analyse the loads within the structure and their evolution with varying process parameters, providing insights for the design and construction of a CBT device at the University of Aveiro. Utilizing Abaqus 2017 commercial software, parameters such as depth setting, distance between bending rolls, thickness, and rolls' diameter, along with simulation-specific variables like the number of passages and friction coefficient, were investigated.

Keywords — continuous-bending-under-tension; high strength steel, numerical simulation

ACKNOWLEGEMENTS

This work is supported by the projects: 2022.05783.PTDC – FCT, DOI 10.54499/2022.05783.PTDC, UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation

REFERENCES

[1] Marko Knezevic, Camille M. Poulin, Xiaodong Zheng, Shijian Zheng, Irene J. Beyerlein, Materials Science & Engineering A 758 (2019) 47–55 https://doi.org/10.1016/j.msea.2019.04.109

[2] Poulin CM, Korkolis YP, Kinsey BL, Knezevic M (2019) Over five-times improved elongation-to-fracture of dual-phase 1180 steel by continuous-bending-under-tension. Material and Design 161:95–105 https://doi.org/10.1007/s12289-019-01530-2.

Innovative Experimental Techniques in Mechanics Combining Impact Dynamics with X-ray Technology

Tomáš Fíla [(a)]

(a) – Czech Technical University in Prague, Faculty of Transportation Sciences
(f) Prague, Czech Republic
(a) – fila@fd.cvut.cz

***Abstract*— State-of-the-art manufacturing technologies such as additive manufacturing, coating and nanotechnology for advanced applications in modern transportation and engineering systems require an in-depth knowledge of mechanical properties and long-term stability of the resulting materials. The performance of modern materials has to be evaluated using environmental conditions relevant for the desired application. As the additive manufacturing is often still not able to produce materials of superior quality and mechanical properties to their conventionally manufactured variants, it is especially important to identify and know the limits of the technology and its applicability. This holds true even more for critical parts of constructions that are subjected to dynamic or fatigue loading. Often, standard methods of mechanical analysis are not sufficient to properly characterize behavior of materials, particularly in very complex modes of deformation such as penetration, localized bending, stability collapse, etc.**

In this contribution, a novel experimental techniques combining dynamic loading at intermediate and high strain rates with high-speed in-situ X-ray radiography are presented as an approach for advanced characterization of complex materials where conventional methods are not sufficient. Potential of this technology for industrial applications in manufacturing, product inspection and testing are demonstrated. Two systems are presented. The first system is designed for intermediate strain rate testing and consists of conventional high power X-ray tube (HP-225, Comet X-ray, Switzerland), in-house developed X-ray camera with Cesium-Iodine scintillation panel (Kiralux 135, Thorlabs, USA + Hamamatsu, Japan) and in-house developed dynamic testing actuator LIMA (LInear Motor dynamic Actuator) based on linear motors. This system is capable of testing at quasi-static and intermediate strain rates with impact velocities of up to 8 m/s and continuous X-ray imaging with typical frame rate of a few hundred frames per second. The second system is designed for high strain rate testing with impact velocities of up to several dozen meters per second. It consists of an in-house developed gas-gun with an instrumented projectile and split Hopkinson bar, flash X-ray system (SCF300, Scandiflash, Sweden), optical mirror, Cesium-Iodine scintillation panel and a high-speed camera (SA-Z, Photron, Japan). X-ray imaging using this system can provide four X-ray projections with a constant exposure time of 20 ns.

In the presentation, representative results revealing performance, advantages and limitations of the individual systems in dynamic testing of complex materials and potential of their use in a variety of industrial applications is discussed. Possibilities of incorporating the systems in modern manufacturing processes of sustainable materials as well as an advanced diagnostic method in smart cities transportation systems are also discussed.

Keywords*— *intermediate and high strain rates; split Hopkinson bar; complex mode of deformation; impact dynamics; X-ray radiography; flash X-ray;

ACKNOWLEGEMENTS

This work is supported by the project Junior Star of the Czech Science Foundation, no. 22-18033M.

TOPIC

1) Sustainable Manufacturing Solutions
   a. Manufacturing Processes & Simulation.

Towards Piezoelectric Oriented Fibrous Platforms for Cardiac Tissue Engineering

Platform Conceptualization, Optimization and Manufacturing

Luís Nascimento [(a,b,c,d)], Gavin Richardson [(c)], Paula Marques [(a,b)], Priscila Melo[(d)], Nathalie Barroca [(a,b)]*

(a) – Department of Mechanical Engineering.; Centre for Mechanical Technology and Automation; (b) – LASI – Intelligent Systems Associate Laboratory ;(c) - Vascular Medicine and Biology Theme, Biosciences Institute; (d) –School of Engineering

(a) - 3810-193 Aveiro, Portugal; (b) – 4800-058 Guimarães, Portugal; (c) - Newcastle upon Tyne, NE1 4EP, UK; (d) Newcastle upon Tyne, NE1 7RU

(a) – luisnascimento12@ua.pt; nbarroca@ua.pt

***Abstract*— The exploitation of naturally occurring body phenomenon holds great promise for the development of novel constructs for its support or regeneration. Amongst these, the integration of piezoelectric actuation as a regulator for the native electro-mechanical cardiac tissue might be advantageous for tissue engineering** [1]**. Nonetheless, research in this field is still in a very early stage with piezoelectric fibrous platforms being engineered by the well-known electrospinning technique, characterized by 2D randomly oriented nonwoven fiber mats. While the technique offers scalability, it lacks precise 3D control, thus not offering personalized architectural cues for cardiac tissue construction.**

Herein, we investigated the application of electrohydrodynamic (EHD) jet printing for the fabrication of diverse 3D platforms with exceptional precision and resolution (fiber diameter < 30 µm) using poly-L-lactic acid (PLLA). EHD utilizes an electric field to eject ink from a conductive nozzle onto a substrate [2]**. Unlike traditional melt-electrowriting, EHD does not rely on polymer fusion, leveraging polymer solution optimization and allowing the use of a wider variety of material choices. To produce PLLA microfibers (1) intrinsic properties related to ink formulation and (2) extrinsic ones related to operating parameters were thoroughly investigated. Solvent selection took into consideration several premises: i) should dissolve PLLA with reasonable viscosity, ii) exhibit an evaporation rate facilitating fiber solidification without clogging the printing needle; iii) conduct applied electric field. Additionally, voltage, needle-to-substrate distance, reduce charge-charge repulsion and restorative viscoelastic forces were also evaluated. Slight changes on these led to different jetting regimes within single architectural drawing. These included fiber coiling, near-field electrospinning, or complex EHD jetting regimes observed particularly when high voltages and feed rates were employed. Nonetheless, structural observation yielded stable PLLA microfiber deposition and stacking in diverse 3D architectures. With this study we established manufacturing principles for EHD jet printing, opening the exploration of diverse polymer options to produce single microfibers layered into precise 3D architectures**.

Keywords*— *Cardiac Tissue Engineering, Piezoelectricity, Electrohydrodynamic Printing

ACKNOWLEGEMENTS

Luís Nascimento thanks FCT for the Ph.D. grant (10.54499/2023.01401.BD). This work was supported by the project Flexobone 2022.02424.PTDC, supported by the Foundation for Science and Technology, in its State Budget component (OE), DOI: 10.54499/2022.02424.PTDC (https://doi.org/10.54499/2022.02424.PTDC) and by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   b. Nanoengineering & Bio-inspired Manufacturing.

REFERENCES

[1] P. J. Gouveia et al., "Flexible nanofilms coated with aligned piezoelectric microfibers preserve the contractility of cardiomyocytes," Biomaterials, vol. 139, pp. 213–228, 2017, doi: 10.1016/j.biomaterials.2017.05.048.

[2] N. Mkhize and H. Bhaskaran, "Electrohydrodynamic Jet Printing: Introductory Concepts and Considerations," Small Science, vol. 2, no. 2, 2022, doi: 10.1002/smsc.202100073.

A comprehensive study on mechanical recycling of HDPE composites

R. Simões [a,b,c], Joana Rodrigues[b], V. Neto [a,c], T. Monteiro [b] and G. Gonçalves [a,c]*

(a) – TEMA, Department of Mechanical Engineering, University of Aveiro, Portugal; (b) - i3N, Department of Physics, University of Aveiro, Portugal; (c) - LASI - Intelligent Systems Associate Laboratory, 4800-058 Guimarães, Portugal.

(*) – raul87@ua.pt

***Abstract*— Over the last decades, plastic usage has grown exponentially, and the management of plastic waste turned into a global crisis. The need for new recycling strategies and implementation of a circular plastics economy, has brought attention to this topic, in an attempt to maximize the value and lifespan of everyday use plastics.[1] The main objective of this study is to investigate the properties of high-density polyethylene (HDPE) during successive closed-loop mechanical recycling via multiple mixture and extrusion cycles. Additionally, the successful incorporation of carbon dots (CDs) into the polymeric matrix, as means to achieve a better performing recycled composite, is also reported. The aim is also to determine if it is possible to use the obtained recycled composites in additive manufacturing, namely 3D printing. The samples were subjected to a detailed structural characterization, differential scanning calorimetry analysis (DSC), X-Ray diffraction analysis (XRD) and photoluminescence analysis. The XRD and DSC characterization revealed that no significant changes in the crystallographic structure or physical properties of the polymer occurred. However, for the composite samples a shift in the position of the main peaks after the first recycling step is visible but no additional effect with the increase of the CDs concentration (up to 1%). Through mechanical testing it was possible to verify for a 0.5% CDs concentration an increase in tensile strength of 17%, with a strain at maximum load of 11%. Furthermore, a distinct optical signature was also observed due to the luminescent nature of CDs, and a clear influence in the optical properties of the polymer was confirmed.[2] A set of 3D printed specimens is also reported, confirming the possibility of the use of recycled HDPE:CDs composites in additive manufacturing. These preliminary results are highly relevant as they have the potential to substantially enhance the life-cycle of HDPE, and to possibly overcome barriers in optical traceability.**

Keywords— HDPE; Carbon dots; Nanocomposites; Recycled polymers; Sustainability.

ACKNOWLEGEMENTS

This work was supported by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020). This work was also supported by the projects LA/P/0037/2020, i3N UIDB/50025/2020&UIDP/50025/2020, LA/P/0037/2020 financed by I.P./MCTES FCT (Fundação para a Ciência e Tecnologia). Raul Simões also acknowledges the support of FCT for the Scholarship 2021.07198. Financial support of project CarboNCT - 2022.03596.PTDC (DOI: 10.54499/2022.03596.PTDC).

TOPIC

1) Sustainable Manufacturing Solutions
   b. Nanoengineering & Bio-inspired Manufacturing.

REFERENCES

[1] E.Kalali, S.Lotfian, M.Shabestari, S.Khayatzadeh, C.Zhao, H.Nezhad, A critical review of the current progress of plastic waste recycling technology in structural materials, Current Opinion in Green and Sustainable Chemistry, Vol. 40, 2023, 100763, DOI:10.1016/j.cogsc.2023.100763.

[2] R. Simões, J. Rodrigues, V. Neto, T. Monteiro, G. Gonçalves, Carbon Dots: A Bright Future as Anticounterfeiting Encoding Agents. Small 2024, 2311526. DOI:10.1002/smll.202311526.

Innovative Leak Detection in Closed Circuits: Aerosolized Luminescent Nanoparticles

G. Marques [a,c], S. O. Pereira[a], J. Rodrigues[a], A. R. F. Carreira[b], L. Rino[a], J. P. Leitão[a], B. P. Falcão[a]

(a) – i3N, Department of Physics, University of Aveiro, 3810-193 Aveiro, Portugal
(b) – Bosch thermotechnology, S. A., 3800-533 Cacia, Portugal
(c) – gabrielsmarques@*ua.pt*

***Abstract*—Tightness tests for domestic water heating equipment have become increasingly stringent, prioritizing equipment performance and user safety. In industrial water heating equipments production, using water to detect leaks is widespread but comes with various drawbacks. The major issue is the reliance on scarce natural resources like water, which also includes additional costs due to the need for drying before packaging. The inability to locate the leakage source has significant environmental and economic consequences, as it leads to the waste of the equipment produced. This happens because conducting individual and meticulous inspections is not commercially feasible.**

To address these challenges, a dry method utilizing aerosolized luminescent nanoparticles as optical probes, to detect and precisely pinpoint the leak site, is being developed. This approach offers several advantages, including being non-toxic, eco and biocompatible, cost-effective, and scalable for industrial use.

The testing platform under development comprises 3 main units responsible for (i) controlling the dispersion of nanoparticles powder in gases, (ii) simulating leaks in pipes, and (iii) detecting and identifying the leak location. Simultaneously, research efforts are directed towards functionalizing sub-20 silica (SiO_2) nanoparticles with fluorescein to produce a highly luminescent dry powder [1-3].

The system is composed of a Venturi eductor coupled with a vacuum pump, where the nanoparticles are accelerated and aerosolized through the perforated testing tube. On the outside, the powder is excited by a UV LED, its luminescence is recorded by a camera and the images are computationally analyzed and treated. A variety of test conditions are being investigated with the functionalized nanoparticles, including different pressure values, diverse carrier gases, and various configurations of the system components. The use of a pressurized chamber filled with the nanoparticles dispersed in gas, to enhance the aerosolization of the nanoparticles through the testing tube, is also under consideration. These preliminary tests show promising results, confirming the feasibility of the different approaches intended to be investigated.

Keywords— Optical leakage detection; Luminescent nanoparticles; Gas dispersion; Image processing; Sustainable and biocompatible nanoparticles.

ACKNOWLEGEMENTS

This work is supported by the projects: LA/P/0037/2020, UIDB/50025/2020, and UIDP/50025/2020- Fundação para a Ciência e a Tecnologia.

The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

TOPIC

1) Sustainable Manufacturing Solutions
   b. Nanoengineering & Bio-inspired Manufacturing.

REFERENCES

[1] M. T. Shah, A. Balouch and E. Alveroglu, "Sensitive fluorescence detection of Ni^{+2} ions using fluorescein functionalized Fe_3O_4 nanoparticles", Journal of Material Chemistry C, vol. 6, pp. 1105-1115, 2018

[2] A. G. Muradova et al., "Development of composite iron oxide fluorescent nanoparticles for nondestructive magnetic particle testing", Nanobiotechnology Reports, vol. 16, pp. 497-504, 2021.

[3] S. Shetty et al., "Highly selective and sensitive aggregation-induced emission of fluorescein-coated metal oxide nanoparticles", Chemistry Open, vol. 10, pp. 1067-1073, 2021.

Microneedles fabrication via DLP for gingiva healing application: Dimensional control

C. Costa Lei [(a,b,c)], *S.G.Patrício* [(b,c)], J.M.Oliveira [(b,c)], J. Mesquita-Guimarães[(a,d)]
(a) – Department of Mechanical Engineering, TEMA; (b) – ESAN; (c) – CICECO; (d) - LASI
(a) Aveiro, Portugal I; (b) – Aveiro, Portugal; (c) – Aveiro, Portugal; (d) – Guimarães, Portugal
(a) – catarinalei@ua.pt

***Abstract*— Periodontal disease affects 50% of the global population and is the sixth most common pathology in the world. In Portugal, 3 out of 4 adults are affected by periodontal disease, including gingivitis. Current treatment strategies focus on the mechanical removal of bacterial biofilms, with systemic antibiotics having associated challenges such as drug resistance and adverse effects [1], [2].**

Transdermal microneedles applied for gingival healing can be an excellent solution acting locally at marginal and attached gingiva areas; therefore, more precise, and targeted therapies may enhance treatment effectiveness while minimizing side effects [3], [4].

This work focuses on the development of hydroxyapatite (HA) microneedles (MNs) using 3D printing technology, digital light processing (DLP), an anchor shape, and an acemannan coating.

Initially, conical MNs were produced to control the precision, resolution, and dimensions. This design provides a basic structure to evaluate the printing capability and characteristics obtained by DLP technology.

Subsequently, a new design of microneedles with an anchored structure was implemented for better fixation and retention at the gingival site. Anchor shape modification aims to improve the effectiveness of MN adhesion.

Therefore, the results will be based on the dimensional control of the CAD model to the printing part, the sintering shrinkage analysis, and relative density and porosity via Micro-CT. Acemannan extraction was performed and subsequently purified and characterized.

The main conclusions suggest that DLP is a proper 3D printing technique to obtain MNs below 700 µm height without cracks or structural defects. Also, it was possible to manufacture an anchored MNs shape of HA with 2 mm of retraction in x and y orientation and 0.8 mm in z orientation. The samples showed high relative density.

Keywords*— *Microneedles; Digital light processing; 3D-printing, dimensional control.

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - 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.

TOPIC

1) Sustainable Manufacturing Solutions
   b. Nanoengineering & Bio-inspired Manufacturing.

REFERENCES

[1] R. Mirghani et al., "Biofilms: Formation, drug resistance and alternatives to conventional approaches," AIMS Microbiol, vol. 8, no. 3, pp. 239–277, 2022, doi: 10.3934/microbiol.2022019.

[2] S. Mckee, A. Lutey, C. Sciancalepore, F. Poli, S. Selleri, and A. Cucinotta, "Microfabrication of polymer microneedle arrays using two-photon polymerization," J Photochem Photobiol B, vol. 229, p. 112424, Apr. 2022, doi: 10.1016/j.jphotobiol.2022.112424.

[3] X. Zhang et al., "Immunomodulatory microneedle patch for periodontal tissue regeneration," Matter, vol. 5, no. 2, pp. 666–682, Feb. 2022, doi: 10.1016/j.matt.2021.11.017.

[4] X. Luo, L. Yang, and Y. Cui, "Microneedles: materials, fabrication, and biomedical applications," Biomed Microdevices, vol. 25, no. 3, p. 20, Sep. 2023, doi: 10.1007/s10544-023-00658-y.

Determination of complexity in recycling plastic materials

Bogoslav Bašić [(a,b,c,)], Victor Neto [(b,c,**)]*
(a) Department of Mechanical Engineering Technology; University of Split, Croatia
(b) Centre for Mechanical Technology and Automation, University of Aveiro, Portugal;
(c) LASI - Intelligent Systems Associate Laboratory, Guimarães, Portugal;
(*) Bogoslav.Basic.00@fesb.hr (**) vneto@ua.pt

***Abstract*— The recycling of plastic materials has become increasingly vital in the global effort to reduce environmental pollution and conserve natural resources. However, the process of recycling plastic presents various challenges, including the complexity of the recycling process itself. Understanding and determining the complexity of recycling plastic materials is essential for optimizing efficiency, reducing costs, and improving sustainability efforts.**

The complexity of recycling plastic materials is influenced by several factors [1], including the diversity of plastic types, contamination levels, and variability in input materials. Plastic materials come in a wide range of types, each with its own properties and characteristics, which can complicate the sorting and processing stages of recycling. Moreover, contamination from foreign materials or other types of plastics can further increase the complexity of the recycling process, requiring additional sorting and cleaning steps to ensure the quality of recycled materials. Variability in input materials, such as fluctuations in plastic composition or size, can also pose challenges for recycling facilities in maintaining consistent processing conditions.

To assess the complexity of recycling plastic materials, various methods for complexity measurement can be employed. These methods often involve analyzing factors such as the number of processing steps, the diversity of input materials, and the level of automation in recycling facilities. One approach to measuring complexity is through process mapping, which involves visually representing the sequence of steps involved in recycling plastic materials and identifying potential bottlenecks or inefficiencies. Another method is the use of complexity metrics, such as the number of material types processed, the variety of equipment used, or the level of manual intervention required in recycling operations.

In optimizing recycling processes, it is essential to conduct process assessments to identify areas of improvement and implement strategies for line balancing [2,3]. Line balancing involves optimizing the distribution of tasks and resources across processing lines to minimize idle time, reduce bottlenecks, and improve overall efficiency. By analyzing the flow of materials and tasks within recycling facilities, line balancing techniques can help streamline operations and maximize throughput. Additionally, process assessments allow for the identification of opportunities for automation, standardization, and quality control measures to enhance the reliability and effectiveness of recycling processes.

In conclusion, the determination of complexity in recycling plastic materials is crucial for optimizing recycling processes and improving sustainability efforts. Factors such as the diversity of plastic types, contamination levels, and variability in input materials contribute to the complexity of recycling operations. Methods for measuring complexity, such as process mapping and complexity metrics, can help assess the level of complexity and identify areas for improvement. Through process assessments and line balancing techniques, recycling facilities can optimize efficiency, reduce costs, and enhance the quality of recycled materials, contributing to a more sustainable future.

Keywords*— *process complexity, complexity measurement, recycling process, line balancing, process assessment acknowlegements

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

1) Sustainable Manufacturing Solutions
   c. Manufacturing for Circular Economy.

REFERENCES

[1] Smith, J., & Johnson, A. (2020). "Complexity Measurement in Recycling Processes." Journal of Waste Management, 35(2), 101-115.

[2] Green, T., et al. (2019). "Optimizing Recycling Processes: Strategies for Line Balancing and Efficiency Improvement." Environmental Science & Technology, 42(3), 207-220.

[3] National Institute of Environmental Health Sciences. (2018). "Recycling Plastic Materials: Challenges and Opportunities." NIEHS Report, 12(4), 55-68..

Weathering and Impact Resistance of Cork-Shear Thickening Fluid (STF) Composites and Structures

*Mafalda Melo [(a, *)], Fábio A. O. Fernandes [(a, b)], Mónica S. A. Oliveira [(a, b)]*
(a) - Centre for Mechanical Technology and Automation (TEMA), Department of Mechanical Engineering, University of Aveiro, Aveiro, Portugal
(b) - Intelligent Systems Associate Laboratory (LASI), Portugal
(*) – mafaldamelo@ua.pt

***Abstract* — Cork is a natural cellular material with exceptional energy absorption capacities [1]. Combined with shear thickening fluids (STFs), which exhibit non-Newtonian behavior characterized by an increase in viscosity under external loads [2], these materials offer novel solutions for impact mitigation. Previous investigations have provided foundational knowledge in this field, exploring the synthesis and properties of cork-STF composites and structures [3, 4, 5]. Building upon those investigations, this research evaluates how these composites and structures endure UV ageing conditions and their subsequent effect on impact resistance. Understanding the performance of cork-STF composites under ageing tests is crucial for assessing their durability and practicality in real-world scenarios. UV exposure and humidity can influence the mechanical properties and structural integrity of these materials over time. Therefore, it is imperative to investigate how these materials evolve and whether they maintain their desired characteristics post-exposure. Moreover, the impact resistance of these composites is of extreme importance in many applications, including head protection gear. In this study, cork-STF composites amd structures were subjected to UV accelerated ageing tests and then subjected to impact tests. Reference samples were submitted to ageing under the same conditions, and their impact performance was also assessed. The findings contribute to the broader understanding of the behavior of cork-STF composites under real-world conditions and the development of more sustainable solutions for future engineering applications due to cork's renewable nature. [6]**

Keywords— Cork, Shear Thickening Fluids (STFs), Impact resistance, Ageing tests

ACKNOWLEDGMENTS

This work was funded by National Funds by FCT – Fundação para a Ciência e a Tecnologia, I.P., in the scope of the project 2022.04022.PTDC with the following DOI: 10.54499/2022.04022.PTDC (https://doi.org/10.54499/2022.04022.PTDC). This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   c. Manufacturing Processes & Simulation.

REFERENCES

[1] S. Gürgen and M. A. Sofuoğlu, "Smart polymer integrated cork composites for enhanced vibration damping properties," *Compos Struct*, vol. 258, p. 113200, Feb. 2021, doi: 10.1016/j.compstruct.2020.113200

[2] T. J. Kang, C. Y. Kim, and K. H. Hong, "Rheological behavior of concentrated silica suspension and its application to soft armor," *J Appl Polym Sci*, vol. 124, no. 2, pp. 1534–1541, Apr. 2012, doi: 10.1002/app.34843

[3] L. Rafaela Sobral de Oliveira, "Development of expanded cork-STF composites for low-energy impacts mitigation," Universidade de Aveiro, Aveiro, 2023.

[4] Lídia Oliveira, Gabriel F. Serra, Selim Gürgen, S. et al. "Shear thickening fluids in cork composites for impact mitigation: the role of fumed silica concentration". Archiv.Civ.Mech.Eng 24, 92 (2024). https://doi.org/10.1007/s43452-024-00909-6

[5] Gabriel F. Serra, Lídia Oliveira, Selim Gürgen, R.J. Alves de Sousa, Fábio A.O. Fernandes, "Shear thickening fluid (STF) in engineering applications and the potential of cork in STF-based composites", Advances in Colloid and Interface Science, Volume 327, 2024, 103157, ISSN 0001-8686, https://doi.org/10.1016/j.cis.2024.103157.

[6] A. S. Tártaro, T. M. Mata, A. A. Martins, and J. C. G. Esteves da Silva, "Carbon footprint of the insulation cork board," J Clean Prod, vol. 143, pp. 925–932, Feb. 2017, doi: 10.1016/j.jclepro.2016.12.028.

Effects of Hydrolytic Aging on Mechanical Properties of Polypropylene-Based Composites with Agro-Waste Fillers

Tatiana Zhiltsova [(a,b,c)], *Andreia Costa* [(d)] and *Mónica S. A. Oliveira* [(a,b,c)]
(a) Mechanical Engineering Department, University of Aveiro; (b) TEMA—Centre for Mechanical Engineering and Automation, University of Aveiro; (c) LASI—Intelligent Systems Associate Laboratory, 4800-058 Guimarães, Portugal; (d) OLI-Sistemas Sanitários, S.A. Travessa de Milão, Esgueira
(b) Aveiro, Portugal; (b) Aveiro, Portugal; (c) Guimarães, Portugal; (d) Aveiro, Portugal
(a) tvzhiltsova@ua.pt

***Abstract*— Natural fiber composites (NFC) are eco-friendly alternatives to synthetic polymers, gaining popularity in various industries. These composites offer unique benefits such as low cost and high mechanical strength. Agro-waste residuals as a source for natural fibre reinforcement have gained an increased interest in industry and academia over recent years, focusing on the sustainability aspect of NFC production by incorporating the locally produced agro-waste as reinforcement. Every year, Portugal produces approximately 50,000 tons of rice husk as byproducts of paddy rice and a significant amount of olive pit residue after oil extraction. The abovementioned natural fibres are normally used for energy generation and their reutilization as reinforcements of NFC, besides constituting an eco-friendly method of disposal, which confers low density, high mechanical strength, and stiffness to NFC. One of the major challenges deterring broader implementation of NFCs is their sensitivity to moisture absorption. The latter is caused by the chemical structure of lignocellulosic fibres and their weak interfacial interaction with the functional group in the polymer matrix, resulting in gaps at the fibre/polymer matrix interface and deterioration of mechanical performance [1]. The work here presented investigates how long-term exposure to water (232 days) affects the mechanical and morphological properties and dimensional stability of the NF polypropylene (PP)-based injection moulded composites reinforced with rice husk (rh) and olive pits (op) of 20 wt.% and 30% wt.%. The water absorption results showed an almost linear increase with the immersion time until reaching the saturation limit, where water absorption became lower than 0.02%. The PPrh composites had a higher saturation water content of 1.42% (20 wt.% rh) and 2.29(30 wt.% rh) in comparison to PPop composites with absorption of 1.08% (20 wt.% op) and 1.52% (30 wt.% op). A larger interface area of the rice husk particles with the PP matrix and its high porosity led to a higher water uptake than PPop [2]. Both rh and op composites became more hydrophilic with increased fibre amount. Tensile elastic modulus has slightly increased (up to 13%) in composites with 30% rh and op fibre content while marginally decreasing (down to 8%) in PP30%op compared to unsaturated counterparts. A similar trend was observed for the flexural modulus enhanced up to 18%. The increased saturated composites' rigidity was confirmed by their higher ultimate tensile strength (up to 17%) and a significant decrease in a rupture strain reaching 39% for PP30%rh. Flexural strength was improved at different levels for all the composites, showing a maximum improvement of 11% in PP20%hr; however, both 30% rh and op composites ruptured in bending, highlighting their fragility after hydrolytic ageing. The results suggest a slight improvement in rice husk and olive pit composites' stiffness due swelling of the fibres, however, making them more susceptible to brittle failure under tension and bending.**

Keywords*— *Natural fibre-reinforced composites; Water absorption; polypropylene.

ACKNOWLEGEMENTS

The present study was developed in the scope of the Project "Agenda ILLIANCE"[C644919832-00000035|Project nº 22], financed by PRR—Plano de Recuperação e Resiliência under the Next Generation EU from the European Union, and supported by the projects: UIDB/00481/2020 and UIDP/00481/2020- Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

1) Sustainable Manufacturing Solutions
   c. Manufacturing for Circular Economy.

REFERENCES

[1] C. Burgstaller, A comparison of processing and performance forlignocellulosic reinforced polypropylene for injection moulding applications, Compos. Part B Eng. 67 (2014) 192–198. https://doi.org/https://doi.org/10.1016/j.compositesb.2014.07.010.

[2] T. Zhiltsova, J. Campos, A. Costa, M.S.A. Oliveira, Sustainable Polypropylene-Based Composites with Agro-Waste Fillers: Thermal, Morphological, Mechanical Properties and Dimensional Stability, Materials (Basel). 17 (2024) 696.

Chain extension of PLA reprocessed multiple-times for FFF

(An option to recover the properties of a degraded thermoplastic)

Tiago Gomes [a,b], Sara Magalhães da Silva [c,d], José Martinho Oliveira [c,d], João Dias-de-Oliveira[a,b], Victor Neto[a,b]

(a) - Department of Mechanical Engineering; TEMA - Centre for Mechanical Technology and Automation, University of Aveiro, 3810-193 Aveiro, Portugal; (b) - LASI - Intelligent Systems Associate Laboratory, Engineering School - University of Minho, 4800-058 Guimarães, Portugal; (c) - School of Design, Management and Production Technologies Northern Aveiro (ESAN); EMaRT Group - Emerging: Materials, Research, Technology, University of Aveiro, 3720-511 Oliveira de Azeméis, Portugal; (d) CICECO - Aveiro Institute of Materials, University of Aveiro, 3810-193 Aveiro, Portugal

tiago.emanuel.gomes@ua.pt

***Abstract*— When aiming for a more circular economy of plastics, one of the main technical challenges that needs to be tackled is material degradation suffered throughout the material's lifecycle** [1]**. One way to mitigate the effects of degradation on material and part properties is to use a chain extender, an additive that can attach to one or more ends of the polymer's molecular chains** [2]**. This can be a route to increase the life of a polymer deemed as too degraded for processing or to meet product-specific technical specifications such as mechanical performance** [3]**.**

In this study, poly(lactic acid) (PLA) was (re)processed for up to three cycles, through extrusion and fused filament fabrication (FFF), starting with virgin pellets at the first cycle. To reprocess the plastic, printed parts were ground in a granulator. Before the last cycle prior to testing, 1,3-bis(4,5-dihydro-2-oxazolyl)benzene (PBO), a chain extender understudied in PLA, was mixed with the plastic in an internal mixer at 0.5, 1.0, and 2.0 wt% concentrations.

Both the effects of reprocessing and those of PBO's concentration were investigated. Fourier-transform infrared (FTIR) spectroscopy did not show detectable differences between formulations or in degraded material, and near infrared (NIR) spectroscopy only revealed a small difference in the virgin polymer. In contrast, differential scanning calorimetry (DSC), double capillary rheology, and tensile tests revealed changes in properties for the reprocessed PLA and their recovery or even improvement relative to the virgin polymer's. Thus, this work shows a pathway for recycling PLA multiple times without sacrificing its performance, further closing the loop on PLA recycling.

Keywords— Closed-loop manufacturing; additive manufacturing; polymer degradation; quality assessment; chain extender.

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020). Authors also acknowledge FCT – Fundação para a Ciência e a Tecnologia for the support given through the PhD scholarship with reference SFRH/BD/143429/2019 (TG).

TOPIC

1) Sustainable Manufacturing Solutions
   c. Manufacturing for Circular Economy.

REFERENCES

[1] T. Kuclourya, R. Monroy, R. Ahmad, "Design of experiments to compare the reprocessing effect with Fused Deposition Modeling printing parameters on mechanical properties of Polylactic Acid specimens towards circular economy", Prog. Rubber, Plast. Recycl. Technol. (2022). doi:10.1177/14777606221145702/ASSET/IMAGES/LARGE/10.1177_14777606221145702-FIG18.JPEG.

[2] W. Limsukon, R. Auras, S. Selke, "Hydrolytic degradation and lifetime prediction of poly(lactic acid) modified with a multifunctional epoxy-based chain extender", Polym. Test. 80 (2019) 106108. doi:10.1016/J.POLYMERTESTING.2019.106108.

[3] T.E. Gomes, M.S. Cadete, J. Dias-de-Oliveira, V. Neto, "Controlling the properties of parts 3D printed from recycled thermoplastics: A review of current practices", Polym. Degrad. Stab. 196 (2022). doi:10.1016/j.polymdegradstab.2022.109850.

TECHNOLOGIES FOR THE WELLBEING

Multiphasic delivery nanosystems for delivery of Li-filled carbon dots for neutron capture therapy

Duarte Almeida [(a,b)], Ricardo J. B. Pinto [(b)], Gil Gonçalves [(a)]
(a) TEMA – Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro
(b) - CICECO – Aveiro Institute of Materials, Department of Chemistry, University of Aveiro
(a,b) - Aveiro, Portugal
(a) – duarte99@ua.pt

***Abstract*— Neutron capture therapy (NCT) defines the combined action of stable isotopes (usually ^{10}B) that can be accumulated in cancer cells and a beam of low-energy neutrons that is captured by the isotope, releasing short-range radiation with an effective cancer cell rate** [1]**. The ^{10}B isotope has shown great efficacy for NCT** [2,3]**. However, a lack of effectiveness has led to the research of other agents, namely lithium, as a possible alternative** [4,5]**. Additionally, as an alternative to the traditional B-containing drugs, which lack the needed biocompatibility for biomedical applications, carbon dots (CDs) have been used, having shown biocompatibility and optical properties that can be useful for bioimaging. However, the use of these ultrasmall (<10 nm) nanoparticles (NPs) as carriers may come with the trade-off of low efficacy due to renal clearance reducing the circulation time** [6]**. This work aimed to develop ^{6}Li-containing CDs encapsulated by core-shell NPs. These carriers optimize delivery by providing size control, as drug delivery systems** [7]**. This precise nanofabrication can be achieved through microfluidics (MFs), a technology that has been shown to be efficient in controlling the size and upscaling fabrication of NPs** [8]**. The fabricated nanocomposites were characterized in terms of chemical composition and structural features and compared to their non-MF counterparts. The MF-based NPs showed a notably lower and narrower size distribution in comparison to the non-MF NPs, showing that MF is able to provide the needed precision for an optimal targeting.**

Keywords — Oncology; drug delivery; microfluidics.

ACKNOWLEDGEMENTS

The financial support of tema is acknowledged by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020; and CENTRO-01-0145-FEDER-022083 - Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund. G.G. and D.A. thank the FCT for the financial support of project CarboNCT – 2022.03596.PTDC (DOI: 10.54499/2022.03596.PTDC).

TOPIC

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

REFERENCES

[1] Lee W, Sarkar S, Ahn H, Kim JY, Lee YJ, Chang Y, et al. "PEGylated liposome encapsulating nido-carborane showed significant tumor suppression in boron neutron capture therapy (BNCT)" Biochem Biophys Res Commun. 2020;522:669–75.

[2] Singh P, Kaur M, Singh K, Meena R, Kumar M, Yun JH, et al. "Fluorescent boron carbide quantum dots synthesized with a low-temperature solvothermal approach for boron neutron capture therapy" Physica E Low Dimens Syst Nanostruct. 2021;132.

[3] Feiner IVJ, Pulagam KR, Uribe KB, Passannante R, Simó C, Zamacola K, et al. "Pre-targeting with ultra-small nanoparticles: Boron carbon dots as drug candidates for boron neutron capture therapy" J Mater Chem B. 2021;9:410–20.

[4] Gonçalves G, Sandoval S, Llenas M, Ballesteros B, Da Ros T, Bortolussi S, et al. "Lithium halide filled carbon nanocapsules: Paving the way towards lithium neutron capture therapy (LiNCT)" Carbon N Y. 2023;208:148–59.

[5] Taskaeva I, Kasatova A, Surodin D, Bgatova N, Taskaev S. "Study of Lithium Biodistribution and Nephrotoxicity in Skin Melanoma Mice Model: The First Step towards Implementing Lithium Neutron Capture Therapy" Life. 2023;13.

[6] Han S, Bouchard R, Sokolov K V. "Molecular photoacoustic imaging with ultra-small gold nanoparticles." Biomed Opt Express [Internet]. 2019;10:3472–83.

[7] Jin R, Qian H, Wu Z, Zhu Y, Zhu M, Mohanty A, et al. "Size Focusing: A Methodology for Synthesizing Atomically Precise Gold Nanoclusters" J Phys Chem Lett. 2010;1:2903–10.

[8] Liu D, Zhang H, Fontana F, Hirvonen JT, Santos HA. "Microfluidic-assisted fabrication of carriers for controlled drug delivery". Lab Chip. 2017;17:1856–83.

Investigating Yttrium-Doped Zirconate Stannate for Proton-Conducting Electrolytes: Understanding Structure, Microstructure, and Electrochemical Transport Characteristics

Laura I.V.Holz [(a,b)], Vanessa C.D. Graça [(a,b)], Sergey M. Mikhalev [(a,b)], Francisco J.A. Loureiro [(a,b)], Duncan P.Fagg [(a,b)]

(a) TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, 3810-193 Aveiro, Portugal.
(b) LASI - Intelligent Systems Associate Laboratory, Portugal.
lauraholz@ua.pt

***Abstract* — The development of high-performance ceramic electrolytes for proton conduction faces challenges such as achieving high densification and maintaining chemical stability in carbonaceous and humidified atmospheres. Barium stannates are recognized for their distinctive structural and chemical properties, making them highly promising as ceramic electrolytes for proton conduction. The incorporation of tin (Sn) offers numerous benefits, including enhanced sinterability and resistance to carbonaceous/humidified atmospheres. This study aims to enhance the electrochemical performance of $BaZr_{0.8-x}Sn_xY_{0.2}O_{3-\delta}$ (x= 0–0.8) by optimizing their composition and structure. These compositions were synthesized via a solid-state approach and confirmed to exhibit pure phase formation across the entire compositional range through X-ray diffraction (XRD) analysis. The introduction of Sn doping resulted in increased sample density and facilitated grain growth, as evidenced by scanning electron microscopy (SEM) investigations. Densification in air at 1600 °C was enhanced with higher Sn content, achieving >90% densification for x ≥0.6. Electrochemical impedance spectroscopy (EIS) was utilized to measure electrical conductivity under nominally dry (pH_2O ~10-7 atm) and wet (pH_2O ~10-2 atm) conditions (550 °C − 850 °C). Protonic, oxygen-ion, and electronic hole partial conductivities were determined using a defect-chemistry model. Samples with higher Sn content exhibited lower protonic transference numbers, aligning with expected behavior based on the acidity scale (i.e., lower hydration enthalpy). This research highlights the need to balance densification and conductivity while preserving enhanced chemical stability. The proposed materials offer enhanced sinterability, resistance to carbonaceous/humidified atmospheres, and improved sample density, making them highly suitable for electrochemical applications such as fuel cells and electrolyzers.**

Keywords*— *Barium stannates, proton ceramic fuel cells, electrolytes, transport properties

ACKNOWLEGEMENTS

The authors acknowledge the grants/projects with references https://doi.org/10.54499/2020.02797.CEECIND/CP1589/CT0030, http://doi.org/10.54499/PTDC/CTM-CTM/2156/2020, https://doi.org/10.54499/PTDC/QUI-ELT/3681/2020, https://doi.org/10.54499/2022.09319.PTDC, https://doi.org/10.54499/2022.02498.PTDC, https://doi.org/10.54499/UIDB/00481/2020, https://doi.org/10.54499/UIDP/00481/2020 from Fundação para a Ciência e a Tecnologia (FCT), and CENTRO-01-0145-FEDER-022083 from Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF).

TOPIC

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

REFERENCES

[1] Y. Wang, A. Chesnaud, E. Bevillon, and G. Dezanneau, Properties of Y-doped BaSnO3 proton conductor, Solid State Ionics, 2012, 214, 45–55.

[2] I.A. Zvonareva, G.N. Starostin, M.T. Akopian, G.K. Vdovin, X.Z. Fu, D.A. Medvedev, Ionic and electronic transport of dense Y-doped barium stannate ceramics for high-temperature applications, J. Power Sources, 565 (2023) 232883.

Capitalizing strain gradients to upgrade bone scaffolding strategies

Nathalie Barroca [a,b]
(a) – TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro
(b)- LASI - Intelligent Systems Associate Laboratory, Universidade do Minho
(a) - 3810-193 Aveiro, Portugal; (b) 4800-058 Guimarães, Portugal
nbarroca@ua.pt

***Abstract*— Tissue engineering uses scaffolds as a microenvironment able to guide their intrinsic ability to synthesize tissue. Within this microenvironment, electrical signaling has revealed a crucial biophysical cue for both tissue development and regeneration regulation [1]. Since the 50's, specific electromechanical couplings were identified in bone tissue, such as flexo- and piezoelectricity, both pointed out as potential contributors in bone remodeling [2-4]. Particularly, bone responds to bending by producing an electromechanical response about 0.2 to 2.3 nC.m^{-1} [3], wherein this response has the capacity to induce an electrical polarization, which – if large enough - can elicit bone cells to mineralize [4]. Symmetry considerations ensure that any material can polarize in response to an inhomogeneous deformation, but not how large or even significant it will be [5], so-that careful quantification of this electromechanical coupling is critical prior envisaging the design of electromechanical transducers based on this effect. So far, research has been conducted mostly on elastomers and solid electrolytes for energy harvesting devices and sensors [6,7]. The experimental evaluation of this electromechanical coupling in biocompatible materials is an unexplored field. In this work, biodegradable thermoplastics commonly exploited for bone tissue engineering, specifically poly(L-lactic acid) and polycaprolactone, as well as their copolymers, were characterized in terms of how large is the electrical polarization in response to strain gradients. While these degradable polymers are the material of choice for some regulated biomedical devices, their relative inertness towards bone tissue calls for adding osteoinductive components. Therefore, composites were prepared by incorporating up to 50 wt% of hydroxyapatite nanoparticles and their electrical response to bending was systematically evaluated. Finally, the implication of this effect for scaffolding design is discussed.**

Keywords*— strain gradients; electrical polarization, bone tissue engineering, biocompatible composites.

ACKNOWLEGEMENTS

This work was supported by the project Flexobone 2022.02424.PTDC, supported by the Foundation for Science and Technology, in its State Budget component (OE), DOI: 10.54499/2022.02424.PTDC (https://doi.org/10.54499/2022.02424.PTDC) and by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

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

REFERENCES

[1] K.A. McLaughlin and M. Levin, "Bioelectric signaling in regeneration: Mechanisms of ionic controls of growth and form", Dev. Biol. Vol.433 pp. 177–189, 2018.

[2] E. Fukada and I. Yasuda, "On the piezoelectric effect of bone", J. Phys. Soc. Japan. Vol.12 pp. 1158–1162, 1957.

[3] F. Vasquez-Sancho, A. Abdollahi, D. Damjanovic and G. Catalan, "Flexoelectricity in bones", Adv. Mater. vol.30 pp. 1–5, 2018.

[4] R. Núñez-Toldrà, F. Vasquez-Sancho, N. Barroca and G. Catalan, "Investigation of the cellular response to bone fractures: evidence for flexoelectricity", Sci. Rep. vol.10 pp. 254, 2020.

[5] P. Zubko, G. Catalan and A.K. Tagantsev, "Flexoelectric effect in solids", Annu. Rev. Mater. Res. Vol.43 pp. 387–421, 2013.

[6] M. Grasinger, K. Mozaffari and P. Sharma, "Flexoelectricity in soft elastomers and the molecular mechanisms underpinning the design and emergence of giant flexoelectricity", Proc. Natl. Acad. Sci. U. S. A. pp.118, 2021.

[7] Y.M. Almazrou, H.A. Albehaijan, J. Jeong and T. Kyu, "Flexoelectricity of multifunctional polymer electrolyte membranes: effect of polymer network functionality", ACS Appl. Energy Mater. vol.4 pp. 12767–12779, 2021.

Oxidation kinetics of cubic niobium oxynitride

Vanessa C.D. Graça[(a,b)], Francisco J.A. Loureiro[(a,b)], Laura I.V.Holz[(a,b)], Glenn C. Mather[(c)], Duncan P.Fagg[(a,b)]

(a) (a) TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, 3810-193, Aveiro; (b) - LASI - Intelligent Systems Associate Laboratory, 4800-058, Guimarães (c) Instituto de Cerámica y Vidrio (ICV), CSIC, C/Kelsen, 5, Madrid, 28049

(a) Aveiro, Portugal (b) Guimarães, Portugal (c) Madrid, Spain
vanessagraca@ua.pt

***Abstract*— In recent years, there has been a growing interest in transition metal oxynitrides (TMNs) due to their attractive properties, such as high electronic and thermal conductivity, high melting points and hardness, as well as high catalytic activity [1]. Among these benefits, niobium oxynitrides have been particularly highlighted for different applications, such as electrocatalysis (*e.g.*, water splitting, nitrogen reduction), antibacterial functions, superconductivity, coatings, and more [2-3].**

Ammonolysis stands out as a promising method for synthesizing these materials. However, the final composition heavily relies on the specific experimental conditions, a factor that remains insufficiently explored in existing literature. Hence, in this work, we investigate how varying ammonolysis conditions affect the crystalline phase formation of niobium oxynitride compounds.

A range of techniques, including XRD, SEM-EDS, TGA/DSC, XPS, and chemical analysis, were employed to characterize the materials thoroughly. Depending on the temperature and duration of ammonolysis, distinct changes in crystallographic structure were observed, transitioning from δ-NbN_xO_y (cubic) to $Nb_4(N,O)_5$ (tetragonal) to ε-NbN (hexagonal) phases, each with composition-dependent variations.

A detailed kinetic analysis was further conducted to comprehend the thermal oxidation behavior of these materials, employing an F_n-type reaction to fit experimental and calculated data. The selection of the Avrami model, describing crystallization kinetics, was justified by identifying amorphous-to-crystalline phase transformations during thermal oxidation. Our findings [4] indicate that samples with higher nitrogen content exhibit greater oxidation resistance, underscoring the potential for tailoring the anion composition, cation/anion ratio, and crystallographic structure through precise control of ammonolysis conditions.

Keywords— ammonolysis, niobium oxynitride, kinetics.

ACKNOWLEDGMENTS

The authors acknowledge the following grants/projects: SFRH/BD/130218/2017, PD/BDE/142837/2018, https://doi.org/10.54499/2020.02797.CEECIND/CP1589/CT0030, http://doi.org/10.54499/PTDC/CTM-CTM/2156/2020, https://doi.org/10.54499/PTDC/QUI-ELT/3681/2020, https://doi.org/10.54499/2022.09319.PTDC, https://doi.org/10.54499/2022.02498.PTDC, https://doi.org/10.54499/UIDB/00481/2020, and https://doi.org/10.54499/UIDP/00481/2020 from Fundação para a Ciência e a Tecnologia (FCT), and CENTRO-01-0145-FEDER-022083 from Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF). Glenn C. Mather thanks the MICINN (Spain) for the concession of project PID2021-123308OB-I00.

TOPIC

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

REFERENCES

[1] P. Patsalas , N. Kalfagiannis , S. Kassavetis , G. Abadias , D. V. Bellas , C. Lekka and E. Lidorikis , "Conductive nitrides: Growth principles, optical and electronic properties, and their perspectives in photonics and plasmonics", Mater. Sci. Eng., R, 2018, 123 , 1 —55 doi:10.1016/j.mser.2017.11.001.

[2] H. Wang , J. Li , K. Li , Y. Lin , J. Chen , L. Gao , V. Nicolosi , X. Xiao and J. M. Lee , "Transition metal nitrides for electrochemical energy applications", Chem. Soc. Rev., 2021 50 1354-1390 doi: 10.1039/d0cs00415d

[3] A. B. Dongil, "Recent Progress on Transition Metal Nitrides Nanoparticles as Heterogeneous Catalysts", Nanomaterials, 2019, 9 (8) 1111 doi: 10.3390/NANO9081111.

[4] V.C.D. Graça, L.I.V. Holz, F.J.A. Loureiro, G.C. Mather, D.P. Fagg " The effect of ammonolysis conditions on the structural properties and oxidation kinetics of cubic niobium oxynitride", J. Mater. Chem. C, 2023, 11 9960-9973 doi: 10.1039/D3TC01068F

Visual air leakage localization by infrared imaging

Ângela Semitela [(a,b)], André F. Girão [(a,b)], António Completo [(a,b)]
(a) – TEMA, Department of Mechanical Engineering, University of Aveiro
(b) - Intelligent Systems Associate Laboratory (LASI)
(a) - Aveiro, Portugal; (b) Guimarães, Portugal
(a) – angela.semitela@ua.pt

***Abstract* — Industrial enterprises such as Bosch Thermotechnology perform an end-of-line functionality test on their products prior to packaging, leading to the waste of natural resources [1]. Indeed, Bosch's final test requires combustion of gases, mainly natural gas and/or hydrogen, and the waste of water to confirm the tightness and safety of its circuits. In this regard, Bosch's is currently implementing a "*dry*" final test, that uses compressed air instead of these natural resources to reduce the overall economic and environmental impact of the process. While this dry test is highly promising for the detection of leaks in the air/water circuits, it is unable to locate them. In this instance, when a leak is detected, it is necessary to remove the product from the production line and perform a time-consuming manual inspection to accurately determine the leak's location. This invariably leads to significant delays in the production line, and an overall reduction in the enterprise's productivity. In this context, it is crucial to investigate suitable methodologies that can automatically and intuitively localize air leaks and be implemented in an industrial environment to optimize the existing dry test.**

Infrared imaging has long been used for gas leak detection in natural gas pipelines [2] and in compressed air systems [3]. Its detection principle is based on temperature differences between the leaked air and the environmental air, allowing the visualization of the leaked gas using thermal cameras. In this regard, infrared thermography was employed, in this work, for air leak detection in a hydraulic circuit from a Bosch's boiler, to assess its potential for leak localization.

So, first, a new leak system was designed with interchangeable leak spots with varying diameters to generate several controlled leak and no-leak scenarios (Figure 1(a)). This leak system was then incorporated within the hydraulic circuit supplied by Bosch to be tested using both the leak quantification device and the infrared thermographic camera. For the visualization experiments, the camera was placed at two detection distances from the circuit, and the detection was performed during an air-tightness test performed by the leak quantification device.

The infrared camera was able to detect air leaking from holes up to 0.25 mm in diameter (corresponding to a leak rate of 2.16 Pa·m^3/s) within distances up to 1 m, given that the leaked air was colder than the environmental air and the material of the leak system. In most cases, the camera itself was able to automatically show the location of the leak as well as its temperature in a small timeframe (4 to 16 sec), as depicted in Figure 1(b). All in all, the results demonstrated the potential of infrared imaging for automatic and intuitive air leak localization in combustion devices during dry test.

Keywords— Infrared imaging; compressed air, leak, dry test, camera, combustion devices.

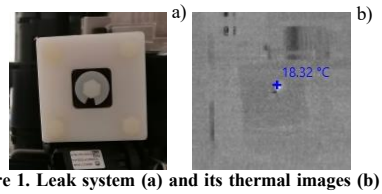

Figure 1. Leak system (a) and its thermal images (b) during test with an exposed leak of 1 mm diameter at 1 m of distance. The camera was able to locate the leak and measure the temperature of the leaked air (18.32 °C).

ACKNOWLEGEMENTS

This work was developed in the scope of the project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union. This work was also supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, (https://doi.org/10.54499/UIDB/00481/2020 and https://doi.org/10.54499/UIDP/00481/2020). The authors would like to acknowledge Bosch Thermotechnology from Aveiro for supplying the boiler's hydraulic circuit.

TOPIC

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

REFERENCES

[1] Bonart J, Hummer P, Drossel W-G. Enhancing End-of-Line Defect Classifications and Evaluating Early Testability for Inline Test Stands Using NVH Measurements. 2021 11th International Electric Drives Production Conference (EDPC), IEEE; 2021, p. 1–6..

[2] Zimmerle D, Vaughn T, Bell C, Bennett K, Deshmukh P, Thoma E. Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions. Environ Sci Technol 2020;54:11506–14.

[3] Dudić S, Ignjatović I, Šešlija D, Blagojević V, Stojiljković M. Leakage quantification of compressed air using ultrasound and infrared thermography. Measurement 2012;45:1689–94.

A robust hydrothermal synthesis method of NH4Zr2(PO4)3, a precursor for HZr2(PO4)3 proton conductor

Lara F. Almeida Paiva [(a)], E. Durana [(b)], Laura I. V. Holz [(b,c)], Manuel P. F. Graça [(a)], Duncan P. Fagg [(b,c)]*

(a) – Department of Physics; University of Aveiro; (b) – Department of Mechanical Engineering; University of Aveiro; (c) – LASI – Intelligent Systems Associate Laboratory
(a) – Aveiro, Portugal; (b) – Aveiro, Portugal; (c) – Guimarães, Portugal.
(a) - lara.paiva@ua.pt

***Abstract*— Hydrogen zirconium phosphate (HZP), characterized by the formula HZr2(PO4)3, has the potential to provide anhydrous protonic conductivity and stability of intrinsic protons up to 650 °C, along with strong chemical resilience in aqueous environments and acid gases [1,2].**

Despite these interesting properties for electrolyte applications such as gas separation, fuel cells, and electrolysers, research on HZP is still in its early stage due to challenges in obtaining the material in a pure phase.

To address this limitation, this study focuses on a novel hydrothermal synthesis method to produce the phase-pure ammonium precursor, NH4Zr2(PO4)3, aiming to establish a refined pathway for synthesizing HZP. The synthesis process emphasizes the critical importance of precisely controlled reaction conditions to achieve pure NH4Zr2(PO4)3 in its cubic and hexagonal structural polymorphs Specifically, a hydrothermal temperature of 150 °C with 2.1 mL of aqueous ammonia yields the cubic phase after a 10-hour reaction, while a temperature of 200 °C with an ammonia volume ranging from 2.3 to 2.4 mL favors the formation of the hexagonal phase.

Additionally, further investigations focus on determining the optimal conditions for converting hexagonal NH4Zr2(PO4)3 into hexagonal HZr2(PO4)3 through thermal treatment at 600 °C for 5 hours, utilizing X-ray diffraction and infrared spectroscopy for assessment. The primary objective of this research is to facilitate broader exploration and utilization of HZP by establishing a robust and reliable synthesis route.

Keywords*— *NZP; HZP; NASICON; protonic conductor; electrolyte; hydrothermal synthesis; fuel cell; green energy; ceramic material.

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

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

REFERENCES

[1] Clearfield A, Roberts BD, Subramanian MA. Preparation of (NH4)Zr2(PO4)3 and HZr2(PO4)3. Mat Res Bull 1984;19:219–26.

[2] Ohta M, Ono A. Protonic conduction in cubic and hexagonal HZr2(PO4)3 crystals. J Mater Sci Lett 1996;15:1487–8.

universidade de aveiro
theoria poiesis praxis
dem
department of mechanical engineering
tema
centre for mechanical technology and automation

Synthesis and characterization of Zinc-doped Barium Zirconium Yttrium Stannate

Carlos M. R. Almeida [(a,b)], Laura I.V. Holz [(a,b)], Francisco J. A. Loureiro [(a,b)], Duncan P. Fagg [(a,b)]
(a) TEMA – Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, Aveiro, Portugal; (b) LASI – Intelligent Systems Associate Laboratory, Portugal
(a) – carlos.almeida@ua.pt

***Abstract*— The development of electrolyte materials for fuel cells and electrolyzers is a key part of the "Strategic Research and Innovation Agenda 2021-2027," which aims to tackle climate change by the adoption of new and efficient processes for energy conversion [1]. With that in mind, our goal is to design protonic ceramic conductors to be used as electrolyte membranes that can operate in the intermediate temperature range (e.g., 500 – 800 °C); a range desirable for stationary energy conversion devices integrated in industrial processes.**

In this work, we aim to synthesize zinc-doped barium zirconium yttrium stannates, with the chemical composition $BaZr_{0.8-x}Sn_xY_{0.16}Zn_{0.04}O_{3-\delta}$, $0 \leq x \leq 0.8$. For that, we modify the route developed in our research group for the synthesis of yttrium doped barium zirconate (BZY) [2]. In the current work, we also utilize ZnO to reduce the sintering temperature from the usual 1600ºC to that of 1300ºC, while also promoting grain growth. Upon characterization of the obtained pellets, we compare them with those of the equivalent composition, without ZnO, annealed at 1600ºC. We perform this characterization using X-ray diffractometry (XRD), scanning electron microscopy (SEM), Archimedes density measurement, and electrochemical impedance spectroscopy (EIS) in wet and dry conditions.

The results show that the compositions synthesized, with x = 0; 0.2; 0.4; 0.6, and 0.8, are phase pure. The pellets annealed at 1300ºC (with ZnO as a sintering aid), show a high level of densification, which is higher than the one of the equivalent ZnO-free compositions annealed at 1600ºC (e.g., for x = 0.4 we obtained 98% densification versus 87%), with larger grain sizes. EIS measurements reflect this altered microstructure, with a higher total conductivity noted for the ZnO-containing samples.

Keywords — Solid Oxide Fuel Cell (SOFC); Yttrium doped Barium Zirconate (BZY); Zinc sintering aids, doped Barium Stannate; electrolyte; electrochemical cell.

ACKNOWLEDGMENTS

The authors acknowledge the grants/projects with references https://doi.org/10.54499/2020.02797.CEECIND/CP1589/CT0030, http://doi.org/10.54499/PTDC/CTM-CTM/2156/2020, https://doi.org/10.54499/PTDC/QUI-ELT/3681/2020, https://doi.org/10.54499/2022.09319.PTDC, https://doi.org/10.54499/2022.02498.PTDC, https://doi.org/10.54499/UIDB/00481/2020, https://doi.org/10.54499/UIDP/00481/2020 from Fundação para a Ciência e a Tecnologia (FCT), and CENTRO-01-0145-FEDER-022083 from Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF).

TOPIC

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

REFERENCES

[1] Governing Board, "Strategic Research and Innovation Agenda 2021 - 2027," 2022. [Online]. Available: https://etipwind.eu/wp-content/uploads/2018-Strategic-Research-Innovation-Agenda.pdf

[2] I. Antunes, A. Brandão, F.M.Figueiredo, J.R.Frade, J.Grácio and D.P.Fagg, "Mechanosynthesis of nanopowders of the proton-conducting electrolyte material Ba(Zr,Y)O3d", Journal of Solid State Chemistry, vol. 182, pp. 2149–2156, May 2009, doi:10.1016/j.jssc.2009.05.027

Characterization and Improvement of Steam Boiler Efficiency

João Pedro Santos Almeida [(a)], Fernando José Neto da Silva [(a,b)], Luís António da Cruz Tarelho [(c,d)]*

(a) Dept. of Mechanical Engineering; University of Aveiro (b) TEMA; University of Aveiro (c) Dept. of Environment and Planning; University of Aveiro (d) Centre for Environmental and Marine Studies (CESAM); University of Aveiro

Aveiro, Portugal

* – jpsalmeida@ua.pt

***Abstract*— This article describes the characterization of a biomass natural convection steam boiler operating with wood chips, [1], wood pellets and the efforts conducted to improve the boiler thermal efficiency and the steam production capacity. The objective of this work is to characterize and improve the production of steam and the thermal efficiency of the boiler. The boiler in analyses was developed based on empirical knowledge. Due to the growing environmental concerns, it was necessary to characterize and improve this equipment, making it more sustainable.**

The boiler under analysis consists of a combustion chamber at the bottom, a heat exchanger in the middle of the boiler and a water preheater in the boiler chimney. Inside the boiler there is a water jacket that contributes to the heat exchange.

Boiler characterization was achieved by an experimental procedure, [1], [2], during which led to the calculation of boiler capacity, efficiency and thermal losses. In the experimental procedure temperatures, flow rates and combustion gases composition were measured in several points of the boiler. These testes were initiated with the biomass combustion, then the data acquisition equipment was turned on. During these testes the anomalies to the normal operation of the boiler were noted and in the end of the testes the obtained data was transferred to the computer, for later treatment.

While operating with pine chips the boiler had an overall efficiency of around 50%. The most significant energy loss occurred through the flue gas exiting through the chimney, [3], which amounted to 70 kW.

After changing to wood pellets the overall efficiency was improved to 68%. Nevertheless, the main thermal losses occurred through the exiting flue gases, [3].

In order to improve the efficiency, the boiler tubular heat exchanger was redesigned and manufactured. The main modifications comprised the increase in the number of tubular pipes, the reduction of their diameter and the increase of the heat exchange area. The design of the new tubular heat exchanger was based upon a simplified model for heat conduction, [4].

The new heat exchanger design consists in a multitube heat exchanger with an area of 7,17 m2 for heat exchange. This heat exchanger was tested with wood pellets and the results showed an improvement of 34% on the steam production capacity and an increase of the useful power from 140 kW to 200 kW, as predicted by the theoretical model. In the refurbished boiler the flue gas losses amounted to 40 kW [3].

Keywords*— *Natural convection steam boiler; energy losses; improvments of boiler performance, experimental testing

ACKNOWLEGEMENTS

This work is supported by the projects: Service provision contract signed between the University of Aveiro and the company Henrique Vieira e Filhos, SA and Centre for Mechanical Technology and Automation, project with the reference UIDB/00481/2020 and UIDP/00481/2020.

TOPIC

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

REFERENCES

[1] C. Serrano, H. Portero, and E. Monedero, "Pine chips combustion in a 50 kW domestic biomass boiler," Fuel, vol. 111, pp. 564–573, 2013, doi: 10.1016/j.fuel.2013.02.068.

[2] V. I. Kuprianov, R. Kaewklum, and S. Chakritthakul, "Effects of operating conditions and fuel properties on emission performance and combustion efficiency of a swirling fluidized-bed combustor fired with a biomass fuel," Energy, vol. 36, no. 4, pp. 2038–2048, 2011, doi: 10.1016/j.energy.2010.05.026.

[3] V. A. F. Costa, L. A. C. Tarelho, and A. Sobrinho, "Mass, energy and exergy analysis of a biomass boiler: A portuguese representative case of the pulp and paper industry," Appl Therm Eng, vol. 152, pp. 350–361, Apr. 2019, doi: 10.1016/j.applthermaleng.2019.01.033.

[4] F. P. Incropera and D. P. Dewitt, Fundamentos de transferência de calor e massa, Sétima edição. Rio de Janeiro, 2014.

Advancing Sustainable Transportation: Green Energy-Dense Fuels from Biomass

J.R. Ravindran [(a)(b)(c)], D. P. Fagg [(a)(b)(c)] , M.C. Coelho [(b) (c)(d)]
(a) - Department of Mechanical Engineering University of Aveiro, Campus Universitário de Santiago
(b) Centre for Mechanical Technology and Automation (TEMA); University of Aveiro, Campus Universitário de Santiago. (c) - LASI – Intelligent Systems Associate Laboratory
(a) (b) Aveiro, Portugal; (c) – Guimarães, Portugal; (d) Department of Environment and Planning University of Aveiro, Campus Universitário de Santiago
jayakrishnanravindran@ua.pt; duncan@ua.pt; margarida.coelho@ua.pt

***Abstract*— As concern about climate change rises worldwide, the need for sustainable alternatives becomes imperative. Producing and using green, energy-dense fuels from biomass seems to be a promising route to decarbonization and the reduction of environmental damage caused due to the use of fossil fuels. This study explores the integrated impacts associated with liquid green fuels made through the electrochemical conversion of biogas while trying to bridge gaps in the literature and promote sustainable transport systems.**

The key areas of this research are:

1. To understand the technical aspects of using liquid green fuels;

2. To quantify the environmental impacts associated with producing and using these fuels in hard-to-electrify transport modes such as maritime sector;

3. To compare the environmental feasibility of these fuels with conventional and other alternative fuels;

4. To analyze the existing policies on these fuels and identifying the best ones for the implementation of these fuels.

A review of biomass conversion technologies, such as anaerobic digestion followed by electrolysis and the Fischer-Tropsch (FT) synthesis shows that, despite their potential to reduce greenhouse gas emissions, there exist some significant contradictions as to their sustainability. Okeke et al. [1] shows a significant reduction in environmental impacts while Navas-Anguita et al. [2] shows an increase in emissions using these fuels. This study aims to clear up the aforementioned discrepancies and provide a comprehensive understanding of the environmental impacts associated with these fuels.

The Lifecycle assessment (LCA) approach using the ReCiPe 2016 methodology (the most commonly used methodology for the LCA of alternate fuels [3]), will be used to assess the complete lifecycle of these fuels, with the system boundary including biomass collection, anaerobic digestion, electrochemical conversion, FT process, refining, transport, and use of these fuels. The functional unit of the study is 1 MJ of energy produced, while impact allocation will be done based on the energy content of final products. The LCA will be conducted on the SimaPro platform.

Preliminary results show that the major global warming potential hotspots in the production process of these fuels are, electricity used from the grid (0.148 kg CO2 eq) and platinum catalyst used in the FT refining process (0.041 kg CO2 eq), while the process with the best environmental results is the anaerobic digestion process due to municipal solid waste reuse (-0.107 kg CO2 eq) per MJ of liquid green fuel produced.

By addressing the inconsistencies [3] existing in the literature and advocating for a standardized approach to LCAs of alternative fuels, this research aims to provide a better understanding of the production and use of these fuels as well as future research directions in LCAs of these fuels. The findings of this study are expected to be used by policymakers and industry stakeholders to make informed decisions about the integration of these fuels into sustainable transport systems.

Keywords— Liquid green fuels, Life cycle assessment, Electrochemical biogas conversion.

ACKNOWLEDGMENTS

Projects UIDB/00481/2020 and UIDP/00481/2020- FCT DOI 10.54499/UIDB/00481/2020, DOI 10.54499/UIDP/00481/2020, PTDC/QUI-ELT/3681/2020, DOI 10.54499/PTDC/QUI-ELT/3681/2020 and 022.09319.PTDC, DOI 10.54499/2022.09319.PTDC and FCT scholarship 2023.02529.BD.

TOPIC

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

REFERENCES

[1] Okeke IJ, Sahoo K, Kaliyan N, Mani S. Life cycle assessment of renewable diesel production via anaerobic digestion and Fischer-Tropsch synthesis from miscanthus grown in strip-mined soils. J Clean Prod 2020;249. https://doi.org/10.1016/j.jclepro.2019.119358.

[2] Navas-Anguita Z, García-Gusano D, Dufour J, Iribarren D. Prospective techno-economic and environmental assessment of a national hydrogen production mix for road transport. Appl Energy 2020;259. https://doi.org/10.1016/j.apenergy.2019.114121.

[3] J. K. Ravindra, D. Fagg, M. C. Coelho .Current Production Routes and Life Cycle Analysis of "Green Energy-Dense Fuels": A Comprehensive Review. Submitted to Renewable and Sustainable Energy Reviews Journal.

3D Printing of Highly Loaded Hydroxyapatite Nanoparticles PLA/PCL Formulations for Bone Grafts

Luís Nascimento [(a,b)], Ângela Semitela [(a,b)], Brian Rodriguez [(c)], Nathalie Barroca [(a,b)]*
(a) – Department of Mechanical Engineering.; Centre for Mechanical Technology and Automation; (b) – LASI – Intelligent Systems Associate Laboratory ;(c) – School of Physics.; University College Dublin
(a) - Aveiro, Portugal ; (b) – Guimarães, Portugal ; (c) Dublin, Ireland
(a) – luisnascimento12@ua.pt; nbarroca@ua.pt

***Abstract*—Technological advancements have propelled the use of additive manufacturing for bone tissue regeneration, particularly towards the biofabrication of complex 3D scaffolds [1]. Despite the extensive development of osteoregenerative biomaterials, significant deficiencies remain in the current products. These encompass challenges in achieving rapid and reproducible replacement of new bone, allied with manufacturing limitations. In fact, alternatives to traditional additive manufacturing techniques (like fused deposition modelling (FDM) or selective laser sintering (SLS)), which can attain suitable microscopic and macroscopic features, are practically non-existent. Although SLS allows the creation of complex geometries with high resolution, its high cost and limited control over porosity and mechanical properties potentially leading to unwanted porosity, limits its applicability [2]. Comparatively, due to its lower cost, FDM has been much more exploited in the last decades. However, the arduous process to produce medical-grade filaments, the necessity of specific pieces of equipment such as an extruder and elevated temperatures involved in melt/extrusion process restricts its applicability and preclude the use of temperature-sensitive components [3].**

Herein, a novel and cheap solvent-based approach was used for the production of scaffolds with varying designs and compositions. Highly viscous solutions composed of poly-L-lactic acid and polycaprolactone copolymers (poly(lactide-*co*-caprolactone)) and hydroxyapatite nanoparticles were printed using simple pneumatic extrusion. This approach allowed to print structures with a high loading of nanoparticles and in a faster manner compared to FDM. Additionally, polymer monomer ratio was also varied (85PLLA/15PCL and 70PLLA/30PCL) to assess possible compositional implications in scaffold physical-chemical and cellular properties. Two main architectures were tested, namely an alternated strut design (ALT) with uniform pore size (600 µm) and high porosity and a graded design presenting a pore size gradient (800 – 250 µm, GRAD). Dimensional analysis (via scanning electron microscopy and micro-CT) confirmed printing fidelity and reliability, with strut diameter and interstrut distance matching modeled values. Additionally, composition played a deep role in the mechanical performance of the scaffolds. Scaffold biological performance was further evaluated through cell viability, calcium and collagen production assays, with all developed scaffolds demonstrating qualified cytocompatibility, making them suitable for load-bearing applications and promising for further bone tissue engineering research.

Keywords— Bone Tissue Engineering; Scaffolds; 3D Printing; Poly(lactide-co-caprolactone); Nano-Hydroxyapatite

ACKNOWLEGEMENTS

Luís Nascimento thanks FCT for the Ph.D. grant (10.54499/2023.01401.BD). This work was supported by the project Flexobone 2022.02424.PTDC, supported by the Foundation for Science and Technology, in its State Budget component (OE), DOI: 10.54499/2022.02424.PTDC (https://doi.org/10.54499/2022.02424.PTDC) and by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

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

REFERENCES

[1] S. Bose, S. Vahabzadeh, and A. Bandyopadhyay, "Bone tissue engineering using 3D printing," Materials Today, vol. 16, no. 12. Elsevier, pp. 496–504, Dec. 01, 2013.

[2] L. Zhang, G. Yang, B. N. Johnson, and X. Jia, "Three-dimensional (3D) printed scaffold and material selection for bone repair," Acta Biomater, vol. 84, pp. 16–33, 2019

[3] Z. Yazdanpanah, J. D. Johnston, D. M. L. Cooper, and X. Chen, "3D Bioprinted Scaffolds for Bone Tissue Engineering: State-Of-The-Art and Emerging Technologies," Front Bioeng Biotechnol, vol. 10, p. 418, Apr. 2022,

Simulation of Electroporation Dynamics in a Tumor-on-a-Chip

João F. Gil [a,c,d], Carla Moura[b], Vania Silverio [c], Gil Gonçalves[d,e]
(a) – CDRSP; PLeiria; (b) – i2A; IPC; (c) - INESC-MN; (d) - TEMA, Mechanical Engineering Department; University of Aveiro; (e) - LASI
(a) – Marinha Grande, Portugal; (b) – Coimbra, Portugal (c) – Lisboa, Portugal; (d) – Aveiro, Portugal; (e) – Guimarães, Portugal
(a) – joao.f.gil@ua.pt

***Abstract*— In this work, we provide a computational simulation framework to clarify the spatiotemporal dynamics of electroporation in a tumor-on-a-chip (ToC) platform. We use the finite element approach implemented in COMSOL Multiphysics to describe the transient electric field distribution, transmembrane voltage, and pore dynamics in response to electrical pulses. This study provides understanding on the kinetics of pore creation and pore radius evolution, as well as their overall impact on electroporation dynamics.**

Electroporation has emerged as a promising approach for improving cellular uptake of therapeutic drugs by temporarily increasing cell membrane permeability using short, high-voltage electrical pulses [1]. However, the intricate relationship between electrical factors and cellular biology remains a challenge. To address this, we put together a computational model that incorporates the geometry of our ToC, biophysical factors such as extracellular medium, cell membrane, and cytoplasmatic conductivity and permittivity, and ordinary differential equations that govern the pore formation dynamics, as well as the evolution of pore radius [2]. As anticipated, our model showed that when electrical pulses ranging from 0,8 to 1 kV/cm are applied, transmembrane voltage increases quickly and reaches high enough values to induce pore creation in the cell membrane. The pore creation kinetics displayed a transient and reversible process with an initial surge and a steady decline. Moreover, the pore radius evolution presented an early phase of expansion followed by stabilization, indicating a dynamic equilibrium between resealing mechanisms and pore formation. Our computational framework provides insights into the fundamental mechanisms of electroporation-mediated drug uptake by predicting spatial and temporal fluctuations in transmembrane voltage and pore dynamics. It is possible to clarify the effects of pulse amplitude, duration, and frequency on pore kinetics and subsequently membrane permeability by modeling various electrical pulse parameters and cellular circumstances. Creating tailored treatment techniques and improving electroporation protocols are possible when computational models and experimental validation are combined. Subsequent endeavors will be centered on enhancing the model to incorporate supplementary elements including multi-cellular dynamics, extracellular matrix interactions, and cell heterogeneity. Moreover, the platform's capacity for scalability and its compatibility with high-throughput screening methods offer prospects for expediting the advancement of customized cancer treatments. To sum up, our computational simulation approach offers a useful instrument for clarifying the electroporation dynamics in microfluidic tumor models.

***Keywords*— Computational simulation; Tumor-on-a-Chip; Eletroporation; Cancer.**

ACKNOWLEGEMENTS

J.F.Gil thanks FCT for the PhD grant UI/BD/151259/2021 (https://doi.org/10.54499/UI/BD/151259/2021).

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

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

REFERENCES

[1] S.N. Campelo, P.H. Huang, C.R. Buie, and R.V. Davalos, "Recent Advancements in Electroporation Technologies: From Bench to Clinic", Annual Review of Biomedical Engineering, vol. 25, pp. 77-100, 2023.

[2] W. Krassowska and P.D. Filev, "Modeling Electroporation in a Single Cell ", Biophysical Journal, vol. 92, pp. 404-417, January 2007.

Comparative analysis of the performance of different configurations of a commercial refrigeration plant operating with R744

Beatriz Riscado[(a)], Fernando Neto Silva [(b)]

(a)-Department of mechanical engineering, University of Aveiro; (b)-TEMA – Centro de Tecnologia Mecânica e Automação, University of Aveiro, Campus de Santiago, Aveiro, 3810-193, Portugal
(a)-beatrizriscado@ua.pt; (b)-fneto@ua.pt;

***Abstract*— Refrigeration was born out of a need to preserve food. It is the only method that allows food to be preserved in its original fresh state. Owing to new regulations restricting the types of refrigerants that can be used, it is imperative to optimize/change them. One of the possible refrigerants to be used in the future is R744 (carbon dioxide), a natural refrigerant that does not aggressively destroy the ozone layer, with a lower direct greenhouse effect, which is widely available [1]. However, the use of this substance in refrigeration systems presents many technical challenges because its properties differ greatly from those of a synthetic refrigerant: its triple point is high, and its critical point is low. Because the critical temperature of R744 is very low (approximately 31 °C), it is difficult for the critical temperature to surpass the ambient temperature. This is a problem because, for heat to be transferred to the environment, to cool the fluid, the condensation temperature must be higher than the ambient temperature, which in many environments is practically unthinkable.**

Various design and control alternatives to conventional cycles have emerged to improve the efficiency of this type of system, making it technically reliable. Many systems running on R744 operate in a transcritical regime (above the critical point), such that the condensing temperature can be higher than the ambient temperature. Recent modifications include the addition of parallel compressors, liquid or vapor injectors, mechanical subcooling (after the gas cooler), and internal heat exchangers [2], [3], [4], [5].

The company Centauro is making such a transition. Centauro Internacional – Trocadores de Calor Lda. is a company in Castelo Branco, a specialist in the fabrication of components for refrigeration and the AVAC industry [6]. To demystify the market's ideas regarding which solution or equipment is ideal for improving the performance of R744 systems, Centauro designed a small-scale supermarket in its Gutlab laboratory.

The aim of this study is to identify and validate which solutions are the best for maximizing energy savings in this supermarket to be installed in the company's laboratory using the simulation software *Pack calculation Pro*. A booster system (with two evaporation stages) with parallel compression was the reference system and was compared with a system with heat recovery in the compressor discharge, a multi-injector system, and a typical booster system without parallel compression. In addition to a technical analysis (with COP measurement and energy efficiency), economic and environmental analyses will also be conducted.

The results show that a transcritical booster system with parallel compression and heat recovery is the most viable solution, technically, economically, and environmentally. The integration of a multi-injetor is not an attractive investment because the equipment cost does not justify the small improvements in the energy performance. Bases on the analysis, heat recovery is a measure that significantly improves the energy efficiency of installations. Overall, this study has allowed to establish the cost-benefit relationship of each technology.

Keywords — Refrigeration; R744; Supermaket; Energy efficiency; Transcritical system

ACKNOWLEGEMENTS

This work was supported by Centauro Internacional-Trocadores de Calor, Lda.

TOPIC

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

REFERENCES

[1] Emerson Climate Tecnologies, "Commercial CO2 Refrigeration Systems Guide for Subcritical and Transcritical CO2 Applications," 2016.

[2] E. Bellos and C. Tzivanidis, "A comparative study of CO2 refrigeration systems," Energy Conversion and Management: X, vol. 1, Jan. 2019, doi: 10.1016/j.ecmx.2018.100002.

[3] G. Mitsopoulos, E. Syngounas, D. Tsimpoukis, E. Bellos, C. Tzivanidis, and S. Anagnostatos, "Annual performance of a supermarket refrigeration system using different configurations with CO2 refrigerant," Energy Conversion and Management: X, vol. 1, Jan. 2019, doi: 10.1016/j.ecmx.2019.100006.

[4] P. Gullo, K. Tsamos, A. Hafner, Y. Ge, and S. A. Tassou, "State-of-the-art technologies for transcritical R744 refrigeration systems - A theoretical assessment of energy advantages for European food retail industry," in Energy Procedia, Elsevier Ltd, 2017, pp. 46–53. doi: 10.1016/j.egypro.2017.07.283.

[5] K. M. Tsamos, Y. T. Ge, Id. Santosa, S. A. Tassou, G. Bianchi, and Z. Mylona, "Energy analysis of alternative CO2 refrigeration system configurations for retail food applications in moderate and warm climates," Energy Convers Manag, vol. 150, pp. 822–829, Oct. 2017, doi:10.1016/j.enconman.2017.03.020.

[6] Centauro Internacional, "O projeto Centauro - Apresentação da empresa." Accessed: Nov. 23, 2023. [Online]. Available: https://centauro.pt/index.php/pt/a-empresa

Designing a eye-readable sensor for hydrogen monitoring and recording

André F. Girão [(a)(b)], António Completo [(a)(b)]*

(a) TEMA, Department of Mechanical Engineering, University of Aveiro; (b) LASI
(a) - Aveiro, Portugal; (b) Guimarães, Portugal
*andrefgirao@ua.pt

***Abstract*— Hydrogen is an essential player for securing the future climate-neutral economy envisioned by the European Commission's net zero emissions scenarios for 2050. Indeed, prominent decarbonization strategies are relying on renewable hydrogen to replace common fossil fuels in industrial, transport, building, and energy sectors [1]. However, the risk of ignitions and explosions due to undetected leaks hampers the implementation of hydrogen-based technologies.**

Taking this into account, hydrogen sensors are indispensable tools to warn users/personal about dangerous atmospheres, ideally guaranteeing real-time monitorization and effective prevention of accidents. The current interest in eye-readable sensors (ERSs) is related to the inherent safety and easy interpretation of their intuitive readouts (*e.g.*, perceptible color changes, reflective-transparent transitions) [2]. Herein, the potential of ERSs to detect hydrogen is overviewed with the purpose of identifying (1) key sensing mechanisms, (2) relevant operational goals, and (3) innovative user-friendly concepts suitable for enclosed spaces and open-air scenarios. Then, a new ERS is presented, highlighting a dual-role design able to combine reversible monitorization with irreversible recording of hydrogen leaks. Such ERS could provide valuable guidelines toward safe and universal access to the green hydrogen economy.

Keywords*— *Hydrogen; Eye-readable sensors

ACKNOWLEGEMENTS

The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Projeto n.º46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union. The authors also acknowledge the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

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

REFERENCES

[1] A. M. Oliveira, R. R. Beswick, Y. Yan, "A green hydrogen economy for a renewable energy society", Curr. Opin. Chem. Eng., vol. 33, pp. 100701, July 2021.

[2] A. Girão, A. Completo, "Eye-readable sensors for intuitive hydrogen monitroing", Int. J. Hydrogen Energy, vol. 64, pp. 593-605, May 2024.

Comparative study of N-rGO and Cr decorated N-rGO as anodes in Lithium-Ion Batteries

Catarina de Lemos [(a,b)], Francisco Loureiro [(a,b)], D. Pukazhselvan [(a,b)], Duncan Paul Fagg [(a,b)]
(a) TEMA - Centre for Mechanical Technology and Automation, University of Aveiro, 3810-193 Aveiro, Portugal
(b) LASI - Intelligent Systems Associate Laboratory, *Guimarães, Portugal*
catarina.lemos@ua.pt

***Abstract*— The current investigation deals with the development of advanced electrode materials to enhance the specific capacity and overall performance of lithium-ion batteries (LIBs). Efforts to improve energy storage capacity and cycle sustainability in LIBs led to focused investigations on anode materials. The theoretical capacity of natural graphite employed as active anode material in commercial Li-ion batteries is 372 mAh/g, whereas only 60 to 80% of the total theoretical capacity of this can be reversibly delivered. Nonetheless, recently several carbonaceous active anode materials were developed, proving that the capacity can be doubled. In particular, reduced graphene oxide (rGO) has shown the potential to replace graphite as ideal base material for the anode of LIBs due to its high electrical and thermal conductivities [1], [2].**

Recently, another promising high surface area porous nanomaterial, metal-organic frameworks (MOFs) have also grown interest as Li+ insertion materials, on the anode side of Li-ion batteries [3]. Considering these, in the current study, we tested using a composite anode made up of reduced graphene oxide (rGO) modified with a metal-organic framework component, MIL-101(Cr), by constructing Li-ion half-cell batteries. In this structure, nitrogen was incorporated as a dopant in the honey-comb graphitic lattice through NH3 treatment to form rGO, following a technique elucidated by Sandoval et al. [4] We have discovered that by conducting NH3 treatment with the presence of MIL-101(Cr) along with GO, the derived structure is Cr decorated - N doped rGO, leading to a resulting structure characterized by a honey-comb lattice. This material was synthesized for the first time, as successfully revealed by the X-ray diffraction (XRD) technique.

The capacity observed by using N-rGO and Cr decorated N-rGO as anodes in Li-ion batteries (CR2032 coin cells) with half-cell configuration is, 425 mAh/g and 537 mAh/g, respectively, at the charge/discharge rate of 100 mA/g. Subsequently, various electrochemical investigations, such as electrochemical impedance spectroscopy (EIS), and cyclic voltammetry (CV) were employed, and it is possible to explore exciting details regarding the Li insertion reaction phenomena in these structures. Our results demonstrate the feasibility of developing novel advanced Li-ion batteries using new anode composites, underscoring their potential for energy storage applications.

Keywords*— *Li-ion battery; energy storage; metal-organic frameworks; electrochemical performance.

ACKNOWLEDGMENTS

The authors acknowledge the following grants/projects: https://doi.org/10.54499/2020.02797.CEECIND/CP1589/CT0030, http://doi.org/10.54499/PTDC/CTM-CTM/2156/2020, https://doi.org/10.54499/PTDC/QUI-ELT/3681/2020, https://doi.org/10.54499/2022.09319.PTDC, https://doi.org/10.54499/2022.02498.PTDC, https://doi.org/10.54499/UIDB/00481/2020, and https://doi.org/10.54499/UIDP/00481/2020 from Fundação para a Ciência e a Tecnologia (FCT), and CENTRO-01-0145-FEDER-022083 from Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF). The authors are also grateful for the financial support granted by the Recovery and Resilience Plan (PRR) and by the Next Generation EU European Funds to the University of Aveiro, through the Agenda for Business Innovation "NGS - Next Generation Storage" (Project no 02/C05-i01.01/2022 with the application C644936001–00000045).

TOPIC

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

REFERENCES

[1]B. Chang et al., "Reduced graphene oxide promoted assembly of graphene@polyimide film as a flexible cathode for high-performance lithium-ion battery †," 2020, doi: 10.1039/d0ra00884b.

[2] J. Park et al., "Reduced Graphene Oxide As an Advanced Anode for Li-Ion Battery," ECS Meeting Abstracts, vol. MA2018-01, no. 5, p. 629, 2018, doi: 10.1149/MA2018-01/5/629.

[3] D. Pukazhselvan et al., "Comparative analyses of MIL-88B(Fe) and MIL-100(Fe) metal organic frameworks as active anode materials for Li ion batteries," Electrochim Acta, vol. 465, p. 142989, Oct. 2023, doi: 10.1016/J.ELECTACTA.2023.142989.

[4] S. Sandoval, N. Kumar,] A Sundaresan, C. N. R. Rao, A. Fuertes, and G. Tobias, "Enhanced Thermal Oxidation Stability of Reduced Graphene Oxide by Nitrogen Doping", 2014, doi: 10.1002/chem.201403833.

universidade de aveiro
theoria poiesis praxis
dem
department of mechanical engineering
tema
centre for mechanical technology and automation

Electrochemical biogas conversion to syngas

Novel electrolytes for proton ceramic membrane reactors

Alfredo S. B. Luemba [(a,b)], Allan J. M. Araújo [(a,b)], Duncan P. Fagg [(a,b)], Francisco J. A. Loureiro [(a,b)]*
(a) TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, 3810-193, Aveiro, Portugal; (b) LASI - Intelligent Systems Associate Laboratory, 4800-058, Guimarães, Portugal
* – buziluemba@ua.pt

***Abstract* — Global energy and climate change are among the world's main problems today, due to an extensive dependence on fossil fuels [1]. In response, the European Union (EU) has organized policies to foster the adoption of efficient and sustainable renewable energy sources, to alleviate the dominance of fossil fuel usage. This massive endeavor finds its foundation in the European Green Deal (EGD), a comprehensive framework designed to propel Europe towards carbon neutrality by 2050 while ensuring the provision of clean, affordable, and secure energy across the EU. Central to this transition is the growing role of biogas in the global energy landscape, as underscored by the International Energy Agency (IEA) [1,2]. Leveraging biogas, particularly through reforming processes, offers a compelling avenue to generate H2-rich gas—a versatile fuel or feedstock pivotal for sustainable chemical production and energy provisioning [3]. Significant advances have been made in developing electrochemical devices to address this goal, by their ability to facilitate a paradigm shift in the clean conversion of chemical energy into electrical energy and vice versa.**

The current work aims to study an electrochemical device to form green syngas (a mixture of CO and H2) from a biogas precursor (CO2 + CH4), by direct electrochemically driven process using a proton-conducting ceramic membrane. A major challenge of this process is to find a suitable electrolyte with a suitable tolerance to the biogas composition (CO2, CH4, and H2S) since current materials suffer from poor chemical stability in these atmospheres. Therefore, this study aims to develop a new electrolyte material that can offer increased chemical resistance. For this purpose, chalcogenide perovskite proton-conducting ceramics made of BaZrS3 (BZS) were successfully synthesized by preparation of the parent oxide BaZrO3 phase using a mechanochemical activation route (under dry milling at 650 rpm for 7 h), followed by calcination in air at 1200 °C for 10 h. Sulfurization was performed at 1050 °C for 24 h, by exposing the oxide powders to a carbon disulfide atmosphere, which was introduced through a bubbler filled with liquid CS2 (99.9%, Sigma-Aldrich), using Ar as the carrier gas (5 mL min-1).

The obtained oxide powders were characterized by X-ray diffraction (XRD), showing pure phase BaZrS3 formation in the orthorhombic system (Pnma space group). Afterward, BZS powders were subjected to a series of stability tests using different atmospheres (CO2 and CH4, 50 mL min-1) at 800 °C for 8 h. Phase integrity was confirmed by performing XRD measurements after each test, revealing no phase decomposition under the testing conditions. The obtained materials can, thus, offer increased tolerance in the presence of carbonaceous atmospheres, being ready for subsequent electrochemical characterization. Their prospective integration in electrochemical devices may offer a new green pathway for syngas production with important applications in both the energy and chemical industry sectors.

Keywords* — *Ceramic electrolyzer; biogas; syngas; electrolyte.

ACKNOWLEDGMENTS

The authors acknowledge the following grants/projects: https://doi.org/10.54499/2020.02797.CEECIND/CP1589/CT0030, https://doi.org/10.54499/PTDC/CTM-CTM/2156/2020, https://doi.org/10.54499/PTDC/QUI-ELT/3681/2020, https://doi.org/10.54499/2022.09319.PTDC, https://doi.org/10.54499/2022.02498.PTDC, https://doi.org/10.54499/UIDB/00481/2020, and https://doi.org/10.54499/UIDP/00481/2020 from Fundação para a Ciência e a Tecnologia (FCT), and CENTRO-01-0145-FEDER-022083 from Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF). In addition, Alfredo Luemba is thankful to Instituto Nacional de Gestão de Bolsas de Estudos (INAGBE-Angola).

TOPIC

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

REFERENCES

[1] Nejat Veziroglu, T. Conversion to hydrogen economy. Energy Procedia 2012, 29, 654–656. https://doi.org/10.1016/j.egypro.2012.09.075.

[2] European Parliament. Fact Sheets on the European Union: Renewable energy 2021. https://www.europarl.europa.eu/factsheets/en/sheet/70/renewable-energy (accessed March, 2023).

[3] International Energy Agency. Global Energy Review: CO2 Emissions in 2021. 2021 n.d. https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf (accessed April, 2024).

Insights into Dura Mater Tissue Behavior: A Computational Perspective

Joana R. Pinto [(a)], Afonso J.C. Silva [(a)], Marcos Gomes [(a)], Fábio AO Fernades[(a)], Ricardo J. Alves de Sousa [(a)]

(a) - *Department of Mechanical Engineering, Campus Universitario de Santiago; University of Aveiro.*
(a) Aveiro, Portugal.

(a) - jrrpinto@ua.pt ; afonso.carvalho.silva@ua.pt ; marcosgomes@ua.pt ; fabiofernandes@ua.pt ; rsousa@ua.pt

***Abstract* — Traumatic Brain Injury represents a significant public health concern due to its role in traumatic death and disability, often caused by head impacts or rapid accelerations [1].**
Despite progress in Finite Element Head Models, research on the field has predominantly focused on males, leading to gaps in understanding gender-related differences [2-4].
Recent studies indicate that women, particularly young women, may be more vulnerable to Traumatic Brain Injury related mortality in sports injuries and intimate partner violence [3,5].
Moreover, the mechanical functions of certain intracranial tissues, such as the dura mater, have traditionally been overlooked [6].
To better understand the mechanical behaviour of the brain and its injured regions in the context of Traumatic Brain Injury, including the dura mater, this study proposes the development of a Finite Element Head Model specific to females.
This model, designed to represent a middle-aged female individual, was developed using medical image-derived geometry and finite element modelling techniques. Validation findings demonstrate a similarity between the numerical displacement curves and experimental observations. Notably, in the model incorporating the dura mater, the numerical results show analogous behaviour to the experimental results, despite minimal variations in the amplitude of the curves.
These advancements highlight the significance of including the dura mater in biomechanical brain modelling and the importance of realistic mechanical properties. This emphasizes the importance of enhancing biomechanical models to better represent anatomical complexity.

Keywords—Finite Element Model; Ttraumatic Brain Injury; Finite Element Technology; Female Head Model; Dura Mater.

TOPIC

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

REFERENCES

[1] Maas, Andrew I, et al. "Traumatic brain injury: progress and challenges in prevention, clinical care, and research". The Lancet Neurology. 2022 Nov;21(11):1004-1060. DOI: 10.1016/S1474-4422(22)00309-X.

[2] Valera, E.M. et al. "Understanding Traumatic Brain Injury in Females: A State-of-the-Art Summary and Future Directions". Journal of Head Trauma Rehabilitation. 2021 Jan, 36, E1–E17. DOI: 10.1097/HTR.0000000000000652.

[3] Biegon, Anat. "Considering biological sex in traumatic brain injury." Frontiers in Neurology, vol. 12, 10 Feb. 2021, DOI: https://doi.org/10.3389/fneur.2021.576366.

[4] Jeon, Y.K.; Jeong, J.; Shin, S.D.; Song, K.J.; Kim, Y.J.; Hong, K.J.; Ro, Y.S.; Park, J.H. "The effect of age on in-hospital mortality among elderly people who sustained fall-related traumatic brain injuries at home: A retrospective study of a multicenter emergency department-based injury surveillance database". Injury. 2022, Oct, 53, 3276–3281. DOI: https://doi.org/10.1016/j.injury.2022.07.036.

[5] Horstemeyer, M.F.; Berthelson, P.R.; Moore, J.; Persons, A.K.; Prabhu2, A.D.R.K. "A Mechanical Brain Damage Framework Used to Model Abnormal Brain Tau Protein Accumulations of National Football League Players". Annals of Biomedical Engineering 2019 Aug, 47, 1873–1888. DOI:10.1007/s10439-019-02294-1.

[6] Walsh, Darragh R., et al. "Mechanical characterisation of the human dura mater, falx cerebri and superior sagittal sinus. Acta Biomaterialia, 2021 Oct 15;134:388-400. Epub 2021 Jul 24. PMID: 34314888. DOI: 10.1016/j.actbio.2021.07.043

The effect of S53P4 Bioactive glass coatings crystallinity and laser surface texturing on zirconia dental implants mineralisation and MC3T3-E1 cell adhesion

L. M. Pereira(a), Q. Nawaz(b), N. M. Ferreira(c), A.B. Pereira(a,d), R. Detsch (b), A. R. Boccaccini(b), J. Mesquita-Guimarães(a,d)

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

(b) - Institute of Biomaterials, University of Erlangen-Nuremberg, Cauerstr. 6, 91058 Erlangen, Germany

(c) - i3N, Physics Department, University of Aveiro, Aveiro, 3810-193, Portugal

(d) -LASI - Intelligent Systems Associate Laboratory, 4800-058 Guimarães, Portugal

(a) – luis.m.pereira@ua.pt

***Abstract*— Recently, laser surface texturing (LST) has been introduced as an eco-substitute for commercial zirconia surface treatment procedures, such as sandblasting and acid-etching, enabling the creation of designed textures, with potential to improve osseointegration [1], [2].**

This study employed three different textures, following the LST parameters obtained in the previous study [3]: i) deep cross-linked grooves, forming squared ridges; ii) superficial micropits ; iii) overlap of the previous textures, resulting in six micro pits per squared ridge.

Then, the samples were coated with S53P4 Bioactive Glass and submitted to two different thermal treatments: conventional treatment (CT) and laser treatment (LT), that generated two different coating crystalline states: CT - partially crystalline; LT - amorphous. The extent of apatite-like deposition after 28 days of immersion in SBF and the viability and adhesion of pre-osteoblastic MC3T3-E1 cells after 48 hours of culture in α-MEM medium were characterized using SEM, XRD, FTIR, and WST.

Although partially crystalline CT coatings showed higher apatite-like deposition, the cell culture tests suggest the combination of micropits texture and amorphous LT coating as the ideal condition for the initial stages of osseointegration, promoting further extracellular matrix deposition, essential for subsequent mineralisation and bone formation.

Keywords*— *Zirconia, Dental Implants, Laser texturing, Bioactive coating, Thermal treatment, Osseointegration, Mineralization behaviour, Cell viability.

ACKNOWLEGEMENTS

This research had the financial support of the following projects UIDB/00481/2020, UIDP/00481/2020, (https://doi.org/10.54499/UIDB/00481/2020) and (https://doi.org/10.54499/UIDP/00481/2020); UIDB/50025/2020, UIDP/50025/2020- FCT - Fundação para Ciência e Tecnologia; and CENTRO-01-0145-FEDER-022083 - Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund. It also acknowledges the CLEAN MOLD project with reference POCI-01-0247-FEDER-070290. Finally, this work acknowledges JECS Trust, for a scholarship to a research stay at the Institute of Biomaterials, University of Erlangen-Nuremberg, Germany, under contract number 2022329.

TOPIC

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

REFERENCES

[1] Y. Sun, J. Sun, X. Wu, Y. Li, X. Li, R. Li, T. Wang, W. Bi, W. Cui, and Y. Yu, "Mechanism of zirconia microgroove surface structure for osseointegration," Mater. Today Adv., vol. 12, p. 100159, 2021, doi: 10.1016/j.mtadv.2021.100159.

[2] "Surfaces of the Straumann® Dental Implant System." Accessed: Oct. 31, 2023. [Online]. Available: https://www.straumann.com/en/dental-professionals/products-and-solutions/dental-implants/dental-implant-surfaces.html

[3] L. M. Pereira, R. Santos, A. B. Pereira, N. M. Ferreira, and J. Mesquita-Guimarães, "Double-size texturisation and biphasic calcium phosphate coatings obtained via laser technologies for bioactive zirconia dental implant surfaces," Open Ceram., vol. 18, no. January, pp. 0–6, 2024, doi: 10.1016/j.oceram.2024.100583.

A promising new graphitic intercalation structure MgO pillared rGO as active anode material for Na and Li ion batteries

D. Pukazhselvan [(a,b)], Catarina de Lemos[(a,b)], Francisco Loureiro[(a,b)], Duncan Paul Fagg[(a,b)]
(a) - TEMA - Centre for Mechanical Technology and Automation, Universidade de Aveiro, 3810-193 Aveiro
(b)LASI - Intelligent Systems Associate Laboratory, Guimarães, Portugal
dpukazh@ua.pt

***Abstract*— Due to its greater abundance, enhanced safety, and cost advantages, sodium garners increased attention as a potential alternative to lithium for rechargeable batteries. However, sodium-ion batteries (NIBs) have not achieved the same commercial success as lithium-ion batteries (LIBs), primarily because of their slower charge/discharge rates. The ionic size of Na is bigger than that of Li (Na^+: 1.02 Å and Li^+: 0.76 Å), which causes transport issues in several layered structures reported in the literature [1]. Studies suggest that by engineering appropriate intercalation/deintercalation structures, this issue can be addressed [2]. In this context, some researchers propose that hybrid nanostructures composed of reduced graphene oxide (rGO) coupled with metals, metal oxides, or halides demonstrate enhanced electrode performance in sodium-ion batteries (NIBs).**

In our laboratory recently we have developed a MgO pillared reduced graphene oxide nanostructure through a simple mecano-thermo-chemical treatment using MgH_2 as a reducing agent [3]. A graphene oxide + 10 wt.% MgH_2 mixture was initially ball milled for 10h and then heated under 1 bar hydrogen atmosphere at 310 ^{0}C for the reaction time of 5h. X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), Raman spectroscopy, and Transmission Electron Microscopy (TEM) techniques confirm that GO to rGO transformation occurred due to the interaction of GO with MgH_2, which also makes Mg get pillared in the form of MgO. The anode was prepared by making a mixture of the active material (MgO pillared rGO), a binder (PVDF) and the current collector (Cu) in 8:1:1 weight ratio. A slurry was made from this mixture by adding pyrrolidine and the slurry was then painted on Cu foil (current collector). Half cell batteries using this anode were constructed in CR2032 coin cell configuration and Li/Na metal was used as counter electrode (electrolytes: $NaPF_6$ in 1M EC/PC for Na ion battery and $LiPF_6$ in 1M EC/DMC). The battery testing was performed by using a Neware galvanostatic electrochemical testing facility. The MgO pillared rGO was employed as active anode material in both Li-ion and Na ion batteries and it is found that 425 mAh/g and 275 mAh/g capacity, respectively, can be observed at the current density of 100 mAh/g. Excellent cyclic stability with over 90% capacity retention has been achieved in both the cases. Especially, exceptional cycle consistency is observed in the case of Na ion battery.

Keywords*— Rechargeable Batteries; Pillared nanostructures; Metal oxides; reducing agents.

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020). D. P acknowledges FCT, Portugal for the financial support with reference CEECIND/04158/2017 (https://doi.org/10.54499/CEECIND/04158/2017/CP1459/CT0029). This work has also received funding from the SMART-ER project, funded by the European Union's Horizon 2020 research and innovation programme under Grant Agreement #101016888. The authors are also grateful for the financial support granted by the Recovery and Resilience Plan (PRR) and by the Next Generation EU European Funds to Universidade de Aveiro, through the Agenda for Business Innovation "NGS - Next Generation Storage" (Project no 02/C05-i01.01/2022 with the application C644936001-00000045).

TOPIC

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

REFERENCES

[1] Cheng, F., Liang, J., Tao, Z., & Chen, J. (2011). Functional materials for rechargeable batteries. *Advanced materials*, *23*(15), 1695-1715.

[2] Pukazhselvan, D., Granadeiro, C. M., Loureiro, F. J., Shaula, A. L., Mikhalev, S. M., Gonçalves, G., & Fagg, D. P. (2023). Comparative analyses of MIL-88B (Fe) and MIL-100 (Fe) metal organic frameworks as active anode materials for Li ion batteries. *Electrochimica Acta*, *465*, 142989.

[3] Pukazhselvan, D., Çaha, I., de Lemos, C., Mikhalev, S. M., Deepak, F. L., & Fagg, D. P. (2024). Understanding the catalysis of chromium trioxide added magnesium hydride for hydrogen storage and Li ion battery applications. *Journal of Magnesium and Alloys*, *12*(3), 1117-1130.

Heat pumps evaporators frosting and defrosting numerical models implementation and adjustment

Alexandra Silva [(a)], Vítor Costa [(a)], João Dias[(a),] ,Hugo Calisto [(b)], Mafalda Henriques[(b)]
(a) – TEMA, Department of Mechanical Engineering, University of Aveiro; (b) – Bosch Thermotechnology
Aveiro, Portugal
alexandrasgvs@ua.pt;joaomdias@ua.pt; v.costa@ua.pt, (b)Hugo.Calisto@pt.bosch.com;
Mafalda.Henriques@pt.bosch.com

***Abstract*— Heat pumps are more environmentally friendly heating solutions when compared to alternatives like gas boilers and electric water heaters. This aligns with goal 12 of the United Nations' 2030 Agenda for Sustainable Development, which aims to promote responsible consumption and production [1]. Therefore, it is of utmost importance to find solutions that improve their operational performance.**

The frost formation in evaporators has a major impact on the heat pumps performance. The layer of frost acts like a thermal insulation, with a strongly negative effect when and where heat transfer must be maintained as high as possible. Additionally, the frost layer reduces the space between evaporator's fins available to air flow, what reduces its operational heat transfer effectiveness. This work proposes the implementation and adjustment of numerical models to simulate frosting and defrosting in heat pump evaporators. Such numerical models aim to predict the thickness and density of the frost layer over time, depending on the atmospheric air conditions and the location where the heat pump outdoor unit is operating. The main objective is to predict when it is necessary to activate the defrosting cycle, reversing the cycle (from the heating cycle to the defrosting cycle) to release the thermal energy required to melt the frost layer. During the defrosting cycle, the heat pump works oppositely to its purpose, thus disabling the system from fulfilling its requirements during that period. Therefore, it is essential that defrosting is only activated when necessary, that is, when the heat transfer between the atmospheric air and the refrigerant is reduced below a given limit. The goal is to adjust (reduce) the frequency of the defrosting cycles without compromising the heat pump performance. However, solving this problem is not easy, as if the frost is not completely melted during the defrost cycle, the remaining liquid water that was not drained from the evaporator can freeze again, forming a solid ice layer that hinders airflow and acts like a thermal insulation layer. This solid ice layer can cause a more severe impact on the heat exchange than the original frost itself. Therefore, the implemented numerical model needs to be calibrated and validated, to be able to accurately model the frosting process on heat pump evaporators. Pursuing this objective, this work implements a defrosting model for the evaporator used in Bosch Thermotechnology's small chassis heat pumps, calibrating and adjusting its parameters relative to the frost model previously implemented by the company. The numerical model analyzes the variation of frost layer thickness and porosity based on heat and mass transfer balance equations, considering variables such as air and refrigerant temperatures, pressures, ambient air humidity, airflow velocity, refrigerant velocity, among others [2]. This work aims to contribute to the increased heat pumps performance, making them a yet more interesting and competitive heating technology. In addition, it is expected that the implemented numerical model will be able to accurately predict the formation of frost in heat pump evaporators, allowing for better planning and control of the defrosting cycle.

***Keywords*— Heat pumps; evaporator; frosting; defrosting; numerical models; frost growth prediction.**

ACKNOWLEGEMENTS

The present study was developed as a collaboration between the University of Aveiro and Bosch Termotechnology, having the support of the projects UIDB/00481/2020 and UIDP/00481/2020. J.M.S. Dias acknowledges the support of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

TOPIC

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

REFERENCES

[1] United Nations Economic Commission for Latin America and the Caribbean (CEPAL). (10th of april of 2024). 2030 Agenda for Sustainable Development. Retrieved from https://www.cepal.org/en/topics/2030-agenda-sustainable-development

[2] Florent Brèque and Maroun Nemer. "Frosting modeling on a cold flat plate: Comparison of the different assumptions and impacts on frost growth predictions". From International Journal of Refrigeration 69 (set. of 2016), pp. 340–360.

Smart Solutions for Sustainable Food Storage: A Review of Technologies and Innovations to Prevent Household Food Waste

Gabriela Garcia [(a)], Sílvia Soares [(a)], Sérgio Tavares [(b)]
(a) - ID+ – DeCA; (b) - TEMA – DEM; University of Aveiro, Portugal
(a) gabriela.garcia@ua.pt

***Abstract*— Food waste has emerged as a pressing global concern with significant environmental, economic, and social implications [1]. Approximately one-third of all food produced each year is lost or wasted [2], representing not only a substantial economic loss amounting to billions of dollars [3] but also a severe environmental impact due to greenhouse gas emissions associated with the production and disposal of unconsumed food [4]. Household food waste stands out as a critical area, contributing to 54 % of the total, amounting to 70 kg per inhabitant [5]. The remaining 46 % of waste stemmed from various stages of the food supply chain. These figures underscore the urgent need for effective solutions to reduce food waste, especially at the household level, where a significant proportion of this waste occurs due to improper storage practices [6], lack of awareness of expiration dates [7], and inefficient inventory management [8].**

In response to this challenge, innovative technologies, especially those based on the Internet of Things (IoT), have been emerged to monitor and manage food storage, aiming to reduce waste and promote more sustainable consumption practices. These solutions range from intelligent monitoring systems to mobile applications and connected devices, providing consumers with tools to optimize their food usage and decrease the amount of products discarded prematurely. For example, real-time monitoring systems allow consumers to track food inventory in their kitchens, facilitating management and efficient use of available food. Additionally, expiration date alerts help prevent unnecessary food disposal by notifying users about items nearing expiration. Additionally, personalized recipe recommendations encourage the creative use of existing ingredients, further reducing waste. Research shows that consumers are increasingly interested in acquiring smarter equipment due to its greater convenience and efficiency in various tasks.

This communication presents an analysis of existing solutions for food monitoring and storage, with a particular focus on technologies that mitigate household food waste. The analysis of scientific literature, market trends and patent databases show that solutions that improve management and storage practices are effective and can reduce food waste by 5 to 7%. However, research gaps remain, particularly in consideration of user's accessibility and usability needs in the design and development of these solutions. This research aligns with international initiatives such as the 2030 Agenda for Sustainable Development, which includes specific targets (Sustainable Development Goal 12.3) aiming to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains by 2030.

Keywords— Sustainable Consumption; Household Food Waste; Smart Kitchen Appliances; Smart Food Storage; IoT.

ACKNOWLEGEMENTS

This work is funded by national funds through the FCT – Fundação para a Ciência e a Tecnologia, I.P. and, when eligible, by COMPETE 2020 FEDER funds, under the Scientific Employment Stimulus – Individual Call (CEEC Individual) – CEECIND/04748/2017/CP1459/CT0048, and under the scope of the projects UIDB/04057/2020, UIDB/00481/2020 and UIDP/00481/2020, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

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

REFERENCES

[1] Spang, E. S., Moreno, L. C., Pace, S. A., Achmon, Y., Donis-Gonzalez, I., Gosliner, W. A., ... & Tomich, T. P. (2019). Food loss and waste: measurement, drivers, and solutions. Annual Review of Environment and Resources, 44, 117-156.

[2] FAO (2011). Global food losses and food waste – Extent, causes and prevention. Rome.

[3] Stenmarck, Â., Jensen, C., Quested, T., Moates, G., Buksti, M., Cseh, B., ... & Östergren, K. (2016). Estimates of European food waste levels. IVL Swedish Environmental Research Institute.

[4] FIAL (2021). The National Food Waste Strategy Feasibility Study – Final Report.

[5] Eurostat (2023). Food waste and food waste prevention - estimates.

[6] Romani, S., Grappi, S., Bagozzi, R. P., & Barone, A. M. (2018). Domestic food practices: A study of food management behaviors and the role of food preparation planning in reducing waste. Appetite, 121, 215-227.

[7] Haque, A., Karunasena, G. G., & Pearson, D. (2022). Household food waste and pathways to responsible consumer behaviour: Evidence from Australia. British Food Journal, 124(11), 3783-3802.

[8] Dobernig, K., & Schanes, K. (2019). Domestic spaces and beyond: Consumer food waste in the context of shopping and storing routines. International Journal of Consumer Studies, 43(5), 480-489.

Identification of energy rationalisation measures and setting of alarms based on a monitoring system

Diana Silva [(a)], Fernando Neto [(a,b)]

(a) – Department of Mechanical Engineering, University of Aveiro, Campus de Santiago, Aveiro, 3810-193, Portugal.

(b) – TEMA – Centro de Tecnologia Mecânica e Automação, University of Aveiro, Campus de Santiago, Aveiro, 3810-193, Portugal.

(a) – dianasilva07@ua.pt

Abstract— Energy efficiency has been getting more and more attention and spotlight in companies and political agendas, especially in the European Union, as a means for a sustainable energy transition. The EU's energy transition is an attempt to protect the environment and mitigate climate change caused by human impact by increasing energy efficiency, improving the role of renewables in energy production, and fostering the efficiency of equipment and buildings. Under Directive (EU) 2023/1791, the EU aims to have a maximum limit of 763 Mtoe for final energy consumption and 993 Mtoe for primary consumption by 2030 [1]. This directive also establishes that EU member states must present annual targets for final energy consumption, as well as national goals for energy efficiency. In Portugal, the topic of energy efficiency appears in the PNEC (National Energy and Climate Plan) targets, reflecting the importance of its contribution to the energy transition. With a growing concern about the efficient use of energy in order to reduce costs and the environmental impact of human activity, companies are increasing the implementation of energy monitoring and management systems as a way of measuring, storing, and analyzing consumption information. In turn, this data will be used to define strategies to increase energy efficiency and reduce emissions.

This work derives from an internship at the company Ecoinside, focused on the design of solutions that contribute to the decarbonization of companies and cities, enforcing the achievement of the goals set in the PNEC and the EU targets for 2030 and 2050 [2]. The focus of the work is on the development of a tool that can receive data from an energy monitoring system, and automatically inform the user of energy and other resources utilization (natural gas, water, gasoline, compressed air), provide automatic notifications for abnormal behaviors or consumptions and help in decision making for energy rationalization measures. As additional functions, a simplified calculator for the sizing of a photo-voltaic panel unit for self-consumption will be included, as well as a compressed air and water leaks detector. This complementary tool will allow for estimates for initial investment, payback period and annual energy savings by introducing data from a single electricity bill, working as a sort of 'pre-budget'. The tool includes several tabs according to what is being analyzed: equipment only analysis, general consumption, compressed air and water consumption, and provides several visual elements like charts of energy consumption by equipment, abnormal behavior detection, as well as filtering by data periods and analysis of the deviation from the reference behavior of the equipment. This tool is meant to be used by Ecoinside and by their clients, that are usually energy-intensive installations, but can also be used and applied to any company that has a monitoring system able to collect data to be processed by Excel. Tests with real customer data were carried out with the tool and it was possible to verify that the panel calculator does in fact show results with a maximum deviation of 20% compared to complete sizing done by the company, and that the tool, as a whole, allows for correct detection of anomalous behavior and informs the user in accordance with what was expected. With this tool, data can be more easily interpreted and help in early detection of equipment issues, that otherwise would most likely only be detected at the time of an energy audit.

Keywords— energy efficiency, energy management systems, energy monitoring systems, energy rationalization, ISO 50001.

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

2) Technologies for the Wellbeing

b. Technologies for the Wellbeing – Innovative Technologies for Smart Cities.

REFERENCES

[1] Directive (UE) 2023/1791 of the European Parliament and of the Counsil, of 13 September 2023, on energy efficiency and amending Regulation (EU) 2023/955 (recast).

[2] "Plano Nacional Energia e Clima 2030," 2019.

Kitchen as ecosystems

Where technology, human interaction and food meet

Sílvia Soares [(a)], Gabriela Madureira [(b)], João Dias-de-Oliveira [(b)]
(a) - ID+ – DeCA; (b) - TEMA – DEM; University of Aveiro, Portugal
(a) silvia.soares@ua.pt

***Abstract*—The integration of technology into kitchen spaces has catalyzed innovation and development, marking a significant transformation in human interaction and meal experiences** [3, 4]**. This communication aims to understand the evolution of kitchen spaces in tandem with technological advancements and examines their impact on human interactions and dining rituals. Additionally, it seeks to delineate the role of designers amidst an industry increasingly prioritizing technological processes over societal well-being. For that, a comprehensive review of existing literature coupled with a PESTEL analysis was conducted to identify the intersection of technology and kitchen dynamics. A graphical chronogram was created to illustrate the evolution of kitchen domains intertwined with technological progress over the last decades. The results show that technology has significantly impacted people's interaction with food and each other in the kitchen space, leading to a gradual disappearance of traditional dining rituals. People are spending less time cooking and eating together at home. However, well-designed technology, particularly Human-Computer Interaction (HCI), can positively influence behaviors, promoting sustainability and a better daily relationship with food. Although the advent of Industry 4.0 technologies has fostered connectivity among kitchen products and processes, enabling circular production and fostering sustainability** [5, 6]**, one can also conclude that the pursuit of innovation over the years has sometimes overlooked environmental and social considerations, risking great adverse impacts on human experiences and society** [7]**. Technology is not merely a collection of gadgets but encompasses how individuals utilize these tools to fulfill their immediate needs, exerting a profound influence on their surroundings** [1, 2]**. Designers play a pivotal role in shaping user's behaviors and surroundings, thus, they could present innovative opportunities to create future environmentally responsible kitchen ecosystems. Ones that enhance rather than detract from human connections and cultural experiences** [8]**. Addressing the challenges posed by technological advancement requires a reevaluation of societal values and a shift towards a more human-centric approach to design and technology integration.**

Keywords— Technology; Kitchen design; Human Interaction; Sustainability; Systems Thinking

ACKNOWLEGEMENTS

This work is funded by national funds through the FCT – Fundação para a Ciência e a Tecnologia, I.P. and, when eligible, by COMPETE 2020 FEDER funds, under the Scientific Employment Stimulus – Individual Call (CEEC Individual) – CEECIND/04748/2017/CP1459/CT0048, and under the scope of the projects UIDB/04057/2020, UIDB/00481/2020 and UIDP/00481/2020, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

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

REFERENCES

[1] M. M. Tehrani, "The Role of Technology in Providing the Efficiency of Kitchen Design," no. May, 2012.

[2] J. van den Eijnde, "The Human Touch in Kitchen Technology: How Technology Changes Our Relationship with Food in the Rational and Ritual Kitchen," APRIA J., vol. 2, no. 1, pp. 68–84, 2020.

[3] J. J. K. Chai, C. O'Sullivan, A. A. Gowen, B. Rooney, and J. L. Xu, "Augmented/mixed reality technologies for food: A review," Trends Food Sci. Technol., vol. 124, no. February, pp. 182–194, 2022.

[4] R.-G. Pasca, A. Gavryushin, Y.-L. Kuo, L. Van Gool, O. Hilliges, and X. Wang, "Summarize the Past to Predict the Future: Natural Language Descriptions of Context Boost Multimodal Object Interaction," 2023, [Online]. Available: http://arxiv.org/abs/2301.09209

[5] B. Namasivayam, "AI for Healthy Meal Preparation in Smart Cities," EAI Endorsed Trans. Smart Cities, vol. 6, no. 4, p. e1, 2022.

[6] A. Ollár, K. Granath, P. Femenías, and U. Rahe, "Is there a need for new kitchen design? Assessing the adaptative capacity of space to enable circularity in multiresidential buildings," Front. Archit. Res., vol. 11, no. 5, pp. 891–916, 2022, doi: 10.1016/j.foar.2022.03.009.

[7] R. B. Rusu, B. Gerkey, and M. Beetz, "Robots in the kitchen: Exploiting ubiquitous sensing and actuation," Rob. Auton. Syst., vol. 56, no. 10, pp. 844–856, 2008.

[8] D. Norman, Design for a better world: meaninful, sustainable, humanity centered. Massachusetts: The MIT Press, 2023.

Smart Solutions for Fruits and Vegetable Storage: An Assessment of Innovative Solutions and Technologies

Fabiana Silva [(a,b)], Sílvia Soares [(a)], Sérgio Tavares [(b)]
(a) - ID+ – DeCA; (b) - TEMA – DEM; University of Aveiro, Portugal
(a) - silvia.soares@ua.pt

***Abstract*— Fruit and vegetables are recognized for their high nutrient content and are fundamental to a healthy and balanced diet. Eating fruit and vegetables every day prevents illnesses such as depression and anxiety and reduces the risk of various chronic diseases such as heart disease, type 2 diabetes, and certain types of cancer [1] [2]. The demand for these foods is increasing due to growing awareness of nutrition and healthy lifestyles. However, due to their seasonal and perishable nature, they pose challenges to storage and preservation. It is estimated that 30 % of the global production of fruit and vegetables is lost during various stages of the value chain [3]. In Europe, the end consumer is responsible for 15 % of this waste [4]. Inadequate storage is identified as one of the main determinants, often resulting from consumers' lack of knowledge about the ideal storage conditions for these crops, which results in early ripening and subsequent waste [5].**

In recent years, smart technologies have received increasing attention as potential solutions to mitigate food waste. These technologies offer innovative approaches to monitoring, preserving, and reducing fruit and vegetable waste in domestic environments. This research presents a comprehensive analysis of existing smart technologies and systems to prevent household fruit and vegetable waste. By analyzing scientific literature, market trends, and database patents, this communication assesses the effectiveness and feasibility of various technological solutions. The research shows that smart appliances have the potential to make a significant contribution to preventing fruit and vegetable waste. These systems integrate sensors with Internet of Things (IoT) technology to monitor real-time parameters such as temperature, humidity, gases content. By collecting and analyzing this data, they autonomously optimize storage conditions to ensure the freshness and quality of fruits and vegetables. Furthermore, these systems have the potential to promote positive behavioral changes among consumers. Through intuitive interfaces and personalized recommendations, they can educate users about optimal storage practices, encourage the consumption of fresh locally sourced foods, and foster sustainable dietary habits. By taking advantage of smart solutions, households can reduce their environmental footprint, save resources, and promote more sustainable consumption practices.

Keywords*— *Food Waste; Smart Technologies; Fruit and vegetable preservation; Household food management; Sustainable consumption

ACKNOWLEGEMENTS

This work is funded by national funds through the FCT – Fundação para a Ciência e a Tecnologia, I.P. and, when eligible, by COMPETE 2020 FEDER funds, under the Scientific Employment Stimulus – Individual Call (CEEC Individual) – CEECIND/04748/2017/CP1459/CT0048, and under the scope of the projects UIDB/04057/2020, UIDB/00481/2020 and UIDP/00481/2020, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

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

REFERENCES

[1] Chai, J. J. K., O'Sullivan, C., Gowen, A. A., Rooney, B., & Xu, J. L. (2022).
[2] Saghafian, F., Malmir, H., Saneei, P., Milajerdi, A., Larijani, B., & Esmaillzadeh, A. (2018). Fruit and vegetable consumption and risk of depression: accumulative evidence from an updated systematic review and meta-analysis of epidemiological studies. British journal of nutrition, 119(10), 1087-1101.

[2] Liu, M. W., Chen, Q. T., Towne Jr, S. D., Zhang, J., Yu, H. J., Tang, R., ... & He, Q. Q. (2020). Fruit and vegetable intake in relation to depressive and anxiety symptoms among adolescents in 25 low-and middle-income countries. Journal of affective disorders, 261, 172-180.

[3] Taglioni, C., Rosero Moncayo, J. & Fabi, C. 2023. Food loss estimation: SDG 12.3.1a data and modelling approach. FAO Statistics Working Paper Series, No. 23-39. Rome, FAO.

[4] Food and Agriculture Organization of the United Nations. (2011). Global food losses and food waste—Extent, causes and prevention. Food and Agricultural Organisation of the United Nations.

[5] Ananda, J., Karunasena, G. G., & Pearson, D. (2022). Identifying interventions to reduce household food waste based on food categories. Food Policy, 111, 102324.

Integrating Safety, Volatility, and Emissions for Urban Road Assessment

Elisabete Ferreira [(a),(c)(d)], Paulo Fernandes[(a),(c),(d)], Eloísa Macedo [(a),(c),(d)], Margarida C. Coelho [(b),(c),(d)]

(a) - Department of Mechanical Engineering; *University of Aveiro ; (b) Department of Environment and Planning; University of Aveiro (c) - Centre for Mechanical Technology and Automation (TEMA) University of Aveiro ; (d) - LASI - Intelligent Systems Associate Laboratory*

(a)– (c) Aveiro, Portugal; (d) – Guimarães, Portugal

(a) elisabetedsf@ua.pt, paulo.fernandes@ua.pt, macedo@ua.pt, margarida.coelho@ua.pt

***Abstract*—Driving behavior significantly impacts safety and emissions, generally categorized as normal or aggressive based on vehicle kinematics and real-world emissions data [1]. Volatility in driving decisions reflects vehicle motion variability, aiding in characterizing behavior and predicting crash propensity [2, 3]. Although past studies have developed integrated indicators for characterizing behavior using several parameters, few have been applied in urban areas. Thus, this study aims to develop an Integrated Driving Indicator (iDI) incorporating safety, volatility, and emissions for urban contexts.**

The iDI was developed through urban simulations in VISSIM microscopic traffic model, generating second-by-second data for each trip. To correlate traffic conflicts with driving failures detected by the iDI, the trajectory files were analyzed in the Surrogate Safety Assessment Model (SSAM). An optimization problem established iDI scores based on safety (defined through time headway and stopping distance), volatility (defined by acceleration and vehicular jerk - the first derivative of acceleration), and emissions parameters (carbon dioxide and nitrogen oxides obtained through Vehicle Specific Power methodology), in which all components where weighted. Then a sensitivity analysis was performed to validate the proposed model. Subsequently, simulations were performed in an urban case study consisting of one signalized intersection, two stop-controlled intersections, and two roundabouts where driving failures were evaluated in three demand periods. Thresholds for failures were based on literature applicable to urban environments [4]. The results were statistically analyzed. The solution with the lowest percentile distribution was selected. SSAM was used to compare results and further evaluate conflicts, indicating that volatility and emissions failures are relevant factors of the iDi.

The proposed iDI offers a comprehensive approach, potentially enhancing driving support systems and addressing safety, emissions, and urban driving challenges.

Keywords— Integrated driving indicator; Driving behaviour; Volatility; Emissions; Sustainable mobility

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020). - FCT - Fundação para a Ciência e a Tecnologia; and CENTRO-01-0145-FEDER-022083 - Centro Portugal Regional Operational Program (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the ERDF. E. Ferreira acknowledges the support for the FCT Ph.D. Scholarship UI/BD/151254/2021 (https://doi.org/10.54499/UI/BD/151254/2021). P. Fernandes thanks FCT/MCTES for the contract granted 2021.02488.CEECIND (https://doi.org/10.54499/2021.02488.CEECIND/CP1659/CT0013.). E. Macedo also acknowledges INTERREG EUROPE Projects SPOTLOG 01C0055 and EMBRACER 01C0056.

TOPIC

2) Technologies for the Wellbeing

b. Technologies for the Wellbeing – Innovative Technologies for Smart Cities.

REFERENCES

[1] G.M.H. Shahariar, M. Sajjad, K.A. Suara, M.I. Jahirul, T. Chu-Van, Z. Ristovski, R.J. Brown, T. Bodisco, "On-road CO2 and NOx emissions of a diesel vehicle in urban traffic". Transp. Res. Part D Transp. Environ, vol.107, 103326, June 2022.

[2] B. Wali, A.J. Khattak, T. Karnowski, „Exploring microscopic driving volatility in naturalistic driving environment prior to involvement in safety critical events—Concept of event-based driving volatility". Accid. Anal. Prev., vol. 139, 105277, November 2019.

[3] Z.H. Khattak, M.D. Fontaine, W. Li, A.J. Khattak, T. Karnowski, "Investigating the relation between instantaneous driving decisions and safety critical events in naturalistic driving environment". Accid. Anal. Prev., vol. 156, 106086, June 2021.

[4] E. Ferreira, P. Fernandes, E. Macedo, M.C. Coelho, "An integrated driving safety-volatility-operational performance indicator". Transp. Res. Procedia, vol. 78, pp. 143-150, 2024.

Modular product architecture applied to a streetlight luminaire

Public streetlighting design for light pollution prevention

David Figueiredo [(a,b)], João Dias-de-Oliveira [(a)], Eduardo Noronha [(b)]*
(a) - DEM, TEMA – Centre for Mechanical Technology and Automation (b) - DeCA, ID+ – Instituto de Investigação em Design, Media e Cultura;
(a,b) - Aveiro, Portugal
(*) – davidf@ua.pt

***Abstract*— Light pollution, defined as the negative effects attributable to the use of excessive or inappropriate artificial light, has risen in the last decades due to the expansion of illuminated urban areas and the switch to LED technology in streetlighting [1]. With the opportunity and demand unfolding for more efficient and sustainable luminaires due to the certification of areas for their pristine night-sky observation conditions, such as in the Alqueva region, Aldeias do Xisto and Parque do Vale do TUA, in Portugal [2], the interdisciplinary integration of design and engineering solutions for the development of lighting systems gains relevance.**

For the prevention of light pollution, the luminaire must be designed accounting for its light distribution, preventing emission of light directly upwards, focusing on the area to be illuminated, performed effectively through the integration of lens that allow for the correct light distribution appropriated to the context [3]. Thus, the ability for the luminaire to be adapted to the different contextual needs is important for light pollution prevention.

Defining product architecture as the assignment of functional elements of a product to its physical building blocks, it serves the purpose of defining the product's basic building chunks' function and interface with the rest of the product [4]. By focusing on the architecture's modularity, it is possible to create a system where its different chunks can be interchangeable to respond to different lighting needs. This allows for a wide variation in configurations with the different functional blocks that offer different light or sensory characteristics.

The goal of this work is to explore how the development of a product architecture focused on modularity can contribute to light pollution mitigation and benefit the luminaire's production and assembly. By following a structured four-step method [4], the product's architecture was defined, creating a schematic of the functional elements, organizing the different clusters, creating the rough geometric layout to analyze the product's feasibility, and identifying the fundamental and incidental interactions, with the variability and adaptation of the luminaire to different contexts then being explored. Through this, it is concluded that that a modular architecture brings benefits to the project's development, namely through the parallel development of components, while allowing for better light pollution prevention by preparing the lighting product for different anticipated contexts.

Keywords*— *light pollution; streetlight; smart lighting; product architecture

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - 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.

This work is supported by the project Celeste - luminária pública para a prevenção da poluição luminosa, financed by "la Caixa" Foundation and supported by ID+, within the scope of the UIDB/04057/2020 project financed by national funds through FCT – Fundação para a Ciência e a Tecnologia, I.P.

TOPIC

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

REFERENCES

[1] F. Falchi et al., 'The new world atlas of artificial night sky brightness', Science Advances, vol. 2, no. 6, pp. 1–26, 2016, doi: 10.1126/sciadv.1600377.

[2] Lusa, 'Parque do Tua certificado como destino turístico mundial para contemplar as estrelas', pp. 1–6, 2020, Accessed: Feb. 06, 2023. [Online]. Available: https://www.publico.pt/2020/08/25/fugas/noticia/parque-certificado-destino-turistico-mundial-contemplar-estrelas-1929226

[3] F. Falchi et al., 'Light pollution in USA and Europe: The good, the bad and the ugly', Journal of Environmental Management, vol. 248, no. 2019, pp. 109–227, 2019, doi: 10.1016/j.jenvman.2019.06.128.

[4] K. Ulrich, S. D. Eppinger, and M. C. Yang, Product Design and Development, Seventh. New York: McGraw-Hill Education, 2020.

Smart Predictive Digital Twins for Water Supply Systems

A Literature Review

Tiago C. Pereira [(a)(b)], Ramon Vilanova Arbos [(b)], António Andrade-Campos[(a)]
(a) - Department of Mechanical Engineering (DEM), Centre for Mechanical Technology & Automation (Tema), University of Aveiro; (b) - Department of Telecommunications and Systems Engineering, Universitat Autònoma de Barcelona
(a) Aveiro, Portugal; (b) – Barcelona, Spain.
(a) – tiago.crispim@ua.pt

***Abstract*— The Digital Twin, first introduced by [1], is a novel technological tool that emulates the behavior of a real-world system. It is composed by a physical entity, its virtual counterpart, and communication channels. By leveraging real-time information exchange, the digital model can be continuously updated to closely mirror reality, achieving high fidelity in its representations.**

With the popularization of Industry 4.0, Digital Twins gained traction in several industrial sectors and the water sector. Digital Twins have shown promise in leveraging real-time communication and accurate hydraulic models for the effective operation of Water Supply Systems (WSSs), as discussed in [2]. Some architectures have been proposed (e.g., [3]) that focus on the management of data streams coming from the sensors, and their subsequent use for control and analytical purposes. The effectiveness of this tool can incentivize the upgrade of sensory infrastructure. As the complexity and volume of data generated continues to escalate, the need for more sophisticated analytical and decision-making tools becomes even more apparent. This has led to the development of Smart Predictive Digital Twins. This new paradigm focuses on integrating/improving the predictive capabilities, and operational control and decision-making processes. This technological progression was incentivized by the popularization of Machine Learning, and Control and Decision Support Systems. Ideally, a Smart Predictive Digital Twin applied to a Water Supply System would be capable to anticipate issues, such as pipe or pump breaks, optimize operations for the purpose of minimization of costs or pressure control, detect and locate water leaks, predictive rehabilitation, optimize design of District Metered Areas (DMA), among other tasks.

Currently, the literature review of Smart Predictive Digital Twins (or Digital Twins) applied to water drinking networks is scarce. As such, to understand future directions of this technology, this work proposes three individual literature reviews on the following topics, applied to drinking water networks: Digital Twins, Machine Learning, and real-time Control & Decision Support Systems. By encompassing the technologies integrated in Smart Predictive Digital Twin, they can be used to assess overall technological implementations and serve to indirectly analyze trends and research gaps. This literature review approach provides a comprehensive overview of the various sub-areas where these technologies are applied in drinking water networks. Among many observations, most notably it was highlighted a significant underutilization of Digital Twins for economically efficient operation of pumps. Furthermore, several emerging trends have been identified and suggest potential synergies in the future application of these technologies. This paper not only presents empirical findings but also showcases how predictive and decision-making capabilities are enhanced by leveraging these emerging tools.

Keywords*— *Digital Twins; Control; Decision Support Systems; Water Supply Systems

ACKNOWLEGEMENTS

This work is supported by the doctoral grant (Ref. 2023.01763.BDANA) financed by the Portuguese Foundation for Science and Technology (FCT) and by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020

TOPIC

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

REFERENCES

[1] Grieves, M., "Digital Twin: Manufacturing Excellence through Virtual Factory Replication", 2015, whitepaper.

[2] Berglund, E.Z., Shafiee, M.E., Xing, L., & Wen, J.J., "Digital Twins for Water Distribution Systems", 2023, *Journal of Water Resources Planning and Management*.

[3] Shafiee, M., Barker, Z.A., & Rasekh, A., "Enhancing water system models by integrating big data", 2018, *Sustainable Cities and Society, 37*, 485-491.

Micromobility in the City

(What about the Safety of Vulnerable Road Users?)

A. Martins [(a)], A. Bastos [(a)], J.P. Santos [(a)], M.S. Henriques [(b)], M.C. Coelho [(a)]
(a) - Centre for Mechanical Technology and Automation (TEMA); (b) - MHSi, Lda Factory Hub
(b) - Aveiro, Portugal; (b) Coimbra, Portugal
(a) – martinsandreiadacosta@ua.pt, abastos@ua.pt, jps@ua.pt, margaridacoelho@ua.pt

***Abstract* — Ensuring urban mobility means providing greater fluidity to urban space. In this sense, micro mobility has emerged in recent years and refers to personal transport that involve small, light duty vehicles, which are mainly designed for short, urban trips. This mobility trend aims to fill gaps in the transport system and offer more efficient and sustainable alternatives for urban travel, especially in congested urban areas [1].**

In recent years, road accident safety has been a major concern, with the World Health Organization's Global Status Report on Road Safety 2018 showing that around 1.35 million people die in road accidents each year [2]. Of particular concern is the fact that about 23 percent of all road traffic deaths are related to two-wheeler (TW) accidents [2]. As personal mobility devices (PMDs) have been widely adopted, the accident rate also increased [3]. Especially electric scooters that have greater speed can be affected by a greater number of accidents, compared to conventional PMDs [4].

Because the movements are often not restricted by lanes, the two-wheeler uses lateral road space more freely and shows obvious multilateral interactions (multi-interaction) with others, bringing issues that endanger traffic safety. Also, the speed of the PMDs should be controlled by recognizing the condition of the road surface [5]. A precise estimation of its impacts on traffic operation and safety is necessary [6].

This work is part of a doctoral research and explored the different factors that cause accidents involving vulnerable road users, namely users of e-scooters, through a literature review on the Scopus database. In this sense, around 50 articles published in the last 10 years were analyzed and all factors were crossed, which were organized into four groups: Driving Behaviors, Infrastructure, Vehicle and Weather Conditions. Furthermore, Artificial Intelligence (AI) techniques that are being used to help in understanding accident factor (such as, characterizing road surfaces) and predicting road safety indicators and trends were also revised. Some concluding remarks are that since the factors that can lead to accidents involving PMD´s are numerous and variable, it is essential that the databases all over the world be improved with qualitative information about the accidents.

Keywords*— *Safety of Vulnerable Road Users; Traffic Accidents; Micromobility; E-Scooters; Artificial Intelligence

ACKNOWLEDEGMENTS

This study was also funded by the PRR – Plano de Recuperação e Resiliência and by the NextGenerationEU funds at Universidade de Aveiro, through the scope of the Agenda for Business Innovation "AM2R - Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas" (Project no. 15 with the application C644866475-00000012).

TOPIC

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

REFERENCES

[1] A.B.R. González, M. R. Wilby, J. J. V. Díaz, R. F. Pozo and C. S. Ávila, " Utilization rate of the fleet: A novel performance metric for a novel shared mobility", Transportation, vol 50, pp.285-301, 2023.

[2] World Health Organization. Global Status Report on Road Safety: Summary; World Health Organization: Geneva, Switzerland, 2018.

[3] N. Dubos, B.Varin and O. Bisson, A better knowledge of powered two wheelers accidents, Transportation Research Procedia, 14, pp. 2274–2283, 2016.

[4] M. Barbo and B. Rodič, Modeling the influence of safety aid market penetration on traffic safety: Case of collision warning system for powered two-wheelers, Accident Analysis and Prevention, 192, 107240, 2023.

[5] J.Cho, Hussen, H.R., Yang and S., Kim, J., Radar-based road surface classification system for personal mobility devices, IEEE Sensors Journal, 23(14), pp. 16343–16350, 2023

[6] Y. Ni, Y. Li, Y. Yuan and J. Sun, An operational simulation framework for modelling the multi-interaction of two-wheelers on mixed-traffic road segments, Physica A: Statistical Mechanics and its Applications, 611, 128441, 2023.

Feasibility Analysis of Autonomous Vehicles as a Public Transportation Option in Suburban Areas

Ana Viriato[a,b], Mónica Rodrigues[a,b], Margarida C. Coelho[a,b], Jorge Bandeira[a,b]
(a) – Centre for Mechanical Technology and Automation; University of Aveiro (b) – Intelligent Systems Associate Laboratory (LASI)
(b) Aveiro, Portugal
(c) Guimarães, Portugal
anaviriato8@ua.pt ; margarida.coelho@ua.pt ; monica.joana@ua.pt ; jorgebandeira@ua.pt

***Abstract*— Autonomous vehicles are widely recognized as an innovative solution with the potential to transform urban mobility, reducing congestion and improving traffic efficiency in metropolitan areas. However, there is a significant gap in current knowledge about the potential of these vehicles to improve accessibility in rural and less densely populated areas, which are often neglected in discussions about autonomous mobility (1).**

The objective of this study aims to fill this gap by exploring the technical and economic feasibility of implementing autonomous vehicles on a suburban bus line.

For this study, bus line 4 was chosen, which connects the center of Aveiro to Carregal, a village far from the center (15 km) with a low population density. The analysis considers several factors, including the operating costs associated with maintaining a fleet of autonomous vehicles, the expected passenger demand, and the infrastructure needed to support this new form of transportation.

The entry and destination data of each passenger on the bus was collected in detail. After collecting the data, an entry and destination matrix was created to enable energy and emissions impact-based analysis. Based on this data, it will be possible to conduct a study on the adoption of autonomous vehicles. The subsequent analysis will evaluate various scenarios involving the integration of autonomous vehicles in the reallocation of public transport passengers.
It will include an assessment of the energy consumption by electric autonomous vehicles, comparing it to the energy consumption of buses. The best way to make the trip will be analyzed, considering passenger density, energy consumption, and emissions. It will be considered whether the best solution is to use only autonomous vehicles to transport people, to use autonomous cars only on the last mile, or to divide the bus route so that it only goes to the point on the route where there is the greatest influx of people, and from then on, the passengers are moved using autonomous vehicles.

Preliminary analysis of the baseline conditions shows that there are problems associated with moving the bus in the more rural areas belonging to the city of Aveiro. The narrow roads, poor maintenance, and sharp bends are examples of factors that make it very time-consuming for passengers to reach their destination, as the bus has to travel at a fairly moderate speed. It is therefore believed that the introduction of autonomous vehicles could offer promising solutions for improving the efficiency and accessibility of public transport in this rural area.

The subsequent analysis will involve a detailed assessment of various scenarios involving autonomous vehicles, including simulations to test different deployment strategies. This will provide insights into the best practices for integrating autonomous vehicles into the existing transportation infrastructure, ensuring that they can effectively address the unique challenges of rural and suburban mobility.

Keywords*— *Autonomous vehicles; Urban mobility; Accessibility in suburban areas; Public transportation; User acceptance; Environmental impacts.

ACKNOWLEDGMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020), DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020) , and P01C0056 EMBRACER - intErconnecting MoBility acRoss europeAn CitiEs and subuRbs. M. Rodrigues thanks to the FCT doctoral scholarship 2022.13303.BD.

TOPIC

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

REFERENCES

[1] Richter MA, Hagenmaier M, Bandte O, Parida V, Wincent J. Smart cities, urban mobility and autonomous vehicles: How different cities needs different sustainable investment strategies. Technol Forecast Soc Change [Internet]. 2022 [cited 2024 Apr 30];184:121857. Available from: http://creativecommons.org/licenses/by/4.0/

INTELLIGENT SYSTEMS

Live and remote data logging device for data acquisition during shipment of products

Jorge Ribeiro [(a)], José Santos [(b)], João Lopes [(c)], José Correia[(d)]
(a, b) – Mechanical Engineering Department; University of Aveiro;
(b) – TEMA- Centre for Mechanical Technology and Automation; University of Aveiro;
(c, d) – Home Comfort Department; Bosch Termotecnologia S.A.
(a,b,c,d) - Aveiro, Portugal;
(a)– jorge.e.ribeiro@ua.pt (b) – jps@ua.pt (c) – joao.lopes5@pt.bosch.com (d) – jose.correia@pt.bosch.com

Abstract— Efficiently managing the transport and storage of goods is a significant challenge for the logistics industry due to the exponential growth of global trade. Logistics is a crucial aspect of the supply chain, covering transport, warehouse management, order processing, and distribution. To increase efficiency, organisations must enhance their logistics processes by reducing delivery times, cutting costs, and optimizing packaging. Reference [1] outlines key considerations for packaging design: protecting the product, minimizing waste and facilitating recycling. The packaging must be designed to ensure the product reaches the consumer in optimal condition.

Packaging testing methods includes simulating physical events that occur during transportation, such as vibrations, impacts, and temperature variations, using various modes of transport. Reference [2] introduced a method for generating vibration simulation schedules for road transport vehicles using pavement profile data, which significantly enhances packaging performance evaluation. The limitations of this method are due to the stationarity of the process and the invariability of vehicle speed. Reference [3] addressed the lack of data on physical events during transport in small carriers such as vans. Data on vibration levels was collected using four data loggers and it was found that the highest acceleration values were recorded vertically in the lower boxes and laterally in the third layer. Although there are still limitations, such as the influence of product mass on vibration and impact intensity, as well as external study characteristics, these advances have greatly improved the field. Efficient design of packaging systems relies on systematically collecting data on physical variables that affect product integrity. The use of data loggers is essential to prevent over-sizing and maintain product protection throughout the supply chain. Recording vibration data is also a crucial step in ensuring the safety and integrity of products during transportation. Vibration tests simulate transportation conditions and identify critical frequencies that could cause damage if not addressed. These tests, which use standards such as ASTM D4169 [4], involve inputting power spectral density (PSD) to visualize critical frequencies, aiding in the prevention of product damage.

This project aims to propose and assess the viability of a portable monitoring device for tracking various parameters during product transportation. The device will monitor temperature, humidity, pressure, impacts location, and vibrations along the transport route. Additionally, a web-based platform will be developed to display real-time data.

It is anticipated that with this device will enable the collection of parameters along the route, allowing a full understanding of the load conditions in which it has been operated. Using the vibrations measurements as example, a power spectral density can be derived from the recorded data, which improves vibration machine simulation processes and moves away from the use of generic standards. This approach aims to provide a more accurate and relevant simulation environment, thereby improving the design of packaging.

Keywords—Transportation logistics; Vibration monitoring device; Data acquisition; Power Spectral Density.

TOPIC

3) Intelligent Systems
   a. Identification System

REFERENCES

[1] Z. Zhu, W. Liu, S. Ye, and L. Batista, 'Packaging design for the circular economy: A systematic review', Sustain. Prod. Consum., vol. 32, pp. 817–832, Jul. 2022, doi: 10.1016/j.spc.2022.06.005.

[2] V. Rouillard, 'Generating Road vibration test schedules from pavement profiles for packaging optimization', Packag. Technol. Sci., vol. 21, no. 8, pp. 501–514, Dec. 2008, doi: 10.1002/pts.840.

[3] P. Böröcz and B. Molnár, 'Measurement and Analysis of Vibration Levels in Stacked Small Package Shipments in Delivery Vans as a Function of Free Movement Space', Appl. Sci., vol. 10, no. 21, p. 7821, Nov. 2020, doi: 10.3390/app10217821.

[4] American Society for Testing and Materials, 'Standard Practice for Performance Testing of Shipping Containers and Systems'. Feb. 12, 2024. doi: 10.1520/D4169-22.

Hole detection system in streets to prevent fall accidents adapted for scooters

Ronaldo Ferreira [(a)], José Paulo Santos [(b)], António Bastos Pereira [(c)], Margarida Coelho [(d)]
(a, b, c, d) – dept. Mechanical Engineering; University of Aveiro
(a, b, c, d) - Aveiro, Portugal
(a) – ronaldoferreira@ua.pt; (b) – jps@ua.pt ; (c) – abastos@ua.pt; (d) – margarida.coelho@ua.pt

Abstract— Every year, the number of deaths resulting from traffic accidents exceeds 1.35 million people worldwide [1]. The losses generated by these accidents are significant and can be around 3 to 5% of the world's Gross Domestic Product (GDP) [2]. In Europe, the costs of traffic accidents are estimated at 300 billion dollars per year, which represents more than 2% of European GDP [3]. In Portugal, in 2019, these costs exceeded US$6.86 million, representing about 3.03% of GDP [4]. Although the majority of traffic accidents involve cars, in recent years, there has been a significant increase in accidents involving electric scooters[5]. Studies show that 79 to 90% of accidents involving electric scooters are caused by falls[6-9]. Other studies show that this problem can be even greater, exceeding 90% of cases [10-12]. Most of these scooter crashes are caused by poor road infrastructure conditions [13]. In Portugal, about 500 accidents were registered in the period from 2019 to 2021, with 395 cases with minor injuries and 13 cases with serious injuries Although there are no official data, it is estimated that this scenario is also similar to other countries, showing that the poor state of conservation of the streets plays a fundamental role in the occurrence of accidents with electric scooters. Therefore, the objective of this work is to propose a solution using computer vision resources to identify potholes in the streets, which can cause the fall of electric scooter drivers. To do this, an object detection system was used with a previously trained neural network, on a set of images of streets with or without holes. The system has been trained to identify the presence of potholes near or very close to the scooters and warn the driver. In the event of a pothole nearby, the system should inform the driver to reduce speed. In case of a pothole too close, the system will inform the driver to break the scooter. A 3-minute video was recorded through a mobile phone on a scooter. The recording was made of a street in the city of Aveiro, containing potholes. Next, video was used as the input variable in the detection system, which was implemented on an Intel Corel7 1.80GHz notebook. The results obtained made it possible to identify whether or not there were potholes in the selected route. The system detected the sections with punctures close to or very close to the scooter and informed the driver to slow down or break the scooter. It is hoped in the future that this system can be used via a mobile phone app, built into scooters, and that scooter riders will be able to use it in real time to avoid potholes, reduce speed or change routes to avoid accidents.

Keywords — object detection system; street hole detection system; traffic accident prevention system; accident prevention system for scooter users.

ACKNOWLEGEMENTS

This study was funded by the PRR – Plano de Recuperação e Resiliência and by the NextGenerationEU funds at Universidade de Aveiro, through the scope of the Agenda for Business Innovation "AM2R – Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas" (Project no. 15 with the application C644866475-00000012).

TOPIC

3) Intelligent Systems
   a. Identification System

REFERENCES

[1] Ahmed, S. K., Mohammed, M. G., Abdulqadir, S. O., El-Kader, R. G. A., El-Shall, N. A., Chandran, D., ... & Dhama, K. (2023). Road traffic accidental injuries and deaths: A neglected global health issue. Health science reports, 6(5), e1240.

[2] WORLD HEALTH ORGANIZATION. Global status report on road safety 2018. World Health Organization, 2019.

[3] A. Linder, J. L. Woodward, P. S. van der Veen, K. Kool, R. Ruiter, ... R. Fischer, "The socio-economic impact of road traffic injuries in the European Union: A systematic review," in Safety Science, vol. 132, pp. 104972, 2020.

[4] Autoridade Nacional de Segurança Rodoviária (ANSR). "Impacto Económico e Social da Sinistralidade Rodoviária." ANSR, 2005. Available at: http://www.ansr.pt/Documents/Impacto_Economico_Social_Sinistralidade_Rodoviaria.pdf . Accessed on: April 25, 2023.

[5] Geo Seguro. "Acidentes com Trotinetes em Portugal". 2023. Available at: https://geoseguro.pt/acidentes-trotinete/

[6] Yannis, G., CRIST, P., & Petraki, V. (2024). Safer Micromobility: Technical Background Report.

[7] Badia, H. and Jenelius, E., Shared e-Scooter Micromobility: A Review of Travel Behavior, Sustainability, Infrastructure, Safety and Policies. 2021.

[8] Heydari, S., Forrest, M. and Preston, J., 2022. Investigating the association between neighbourhood and e-scooter safety. Sustainable Cities and Society. 83,

[9] Lime. 2022. Reports from New York and Paris have the same conclusion: Shared E-Scooters are Safe. https://www.li.me/blog/reports-from-new-york-and-paris-have-the-same-conclusion-shared-e-scootersare- safe (Accessed on 18 January 2023).

[10] Brownson AB, Fagan PV, Dickson S, Civil ID. Electric scooter injuries atAuckland City Hospital. N Z Med J. 2019 Nov 8;132(1505):62-72. PMID: 31697664.

[11] Trivedi TK, Liu C, Antonio ALM, Wheaton N, Kreger V, Yap A, Schriger D, Elmore JG. Injuries Associated With Standing Electric Scooter Use. JAMA Netw Open. 2019 Jan 4;2(1):e187381. doi: 10.1001/jamanetworkopen.2018.7381. PMID: 30681711; PMCID: PMC6484536.

[12] Blomberg SNF, Rosenkrantz OCM, Lippert F, Collatz Christensen H. Injury from electric scooters in Copenhagen: a retrospective cohort study. BMJ Open. 2019 Dec 22;9(12):e033988. doi: 10.1136/bmjopen-2019-033988. PMID: 31871261; PMCID: PMC6936991.

[13] Transportstyrelsen (2020) Utredning behov av förenklade regler för eldrivna enpersonsfordon. Delrapport två – redovisning 60 olyckor och tillbud. TSV 2019-5394.

An automatic system for detecting defects in the painting of combustion device covers

João Silva [(a)], Rodrigo Rito [(b)], António Completo [(a,c)], Ângela Semitela [(a,c)], Diogo Costa [(d)], José Oliveira [(d)], Paulo Antunes [(b)], Luis Rino [(b)], Nuno Lau [(c,e)], José Santos [(a,c)]

(a) TEMA, Department of Mechanical Engineering, University of Aveiro
(b) I3N & Department of Physics of the University of Aveiro, Campus Universitário de Santiago, Portugal
(c) Intelligent Systems Associate Laboratory (LASI)
(d) Bosch Termotecnologia S.A.
(e) IEETA – Institute of Electronics and Informatics Engineering of Aveiro, Department of Electronics, Telecommunications and Informatics, University of Aveiro
(a, b, d, e) - Aveiro, Portugal; (c) - Guimarães, Portugal
(a) – jpls@ua.pt

***Abstract* — The industrial competitiveness has increased exponentially in recent years, resulting in a search for faster and more precise processes. The implementation of automatic systems is a key to improve the quality and decrease the production time.**

The product quality control is a pivotal section of a production line. It requires a rigorous verification of the products and the exclusion of any type of defect, achieving the highest possible degree of customer satisfaction. Currently in most factories, this work is performed manually by specialized workers, which implies the possibility of errors of human nature.

In this case, the defect detection of the painting process of combustion devices covers plays an extremely important role. Several types of defects appear: e.g. scratches, dents, lack or excess of paint, etc. Workers responsible for the inspection of these parts have the responsibility to decide whether the part is acceptable or not based on pre-defined acceptance parameters. They often place themselves in unergonomic and uncomfortable positions for long periods of time, affecting the quality of the inspection.

In this paper, an automatic system for detecting defects in the painting process of combustion device covers was proposed. This system was based on the image acquisition and image processing in real time, using cameras, and must be effective taking into account the lighting conditions and positioning of each component. At the end of the inspection of a single part, the system sent a message whether the part is acceptable or not based on the acceptance parameters.

At the inspection zone, the deflectometry inspection method was employed [1]. This is a method widely applied in defect detection systems, due to its success. It is based on the projection of a pattern, usually a fringe pattern, onto the inspection surface which becomes deformed at the location of the defect, making it more evident. Each type of defect has its unique geometry when detected with this method, making them easily distinguishable from each other. For the algorithms, object detection algorithms were used, namely the YOLO model [2, 3].

The work showed some advances in terms of laboratory deflectometry tests which were carried out with a TV or a projector and various components in order to find the best configuration. It shows advances in the detection algorithms too, where a model to detect only crater-type defect was developed using the YOLOv8 algorithm. It obtained a precision, recall and mAP50 of 94,6%, 86,7% and 91,6%, respectively. The mAP50-95 obtained was 42,8%, meaning that this is the value of the average of the mAP (mean average precision) calculated at varying IoU thresholds, ranging from 0.50 to 0.95. This can be improved by employing various bounding box techniques.

Keywords* — *Quality Control; Deflectometry; Computer Vision; Machine Learning; Defect Detection; Object detection

ACKNOWLEGEMENTS

This work was developed in the scope of the project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union. This work was also supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, (https://doi.org/10.54499/UIDB/00481/2020 and https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   a. Identification System

REFERENCES

[1] J. Burke, A. Pak, S. Höfer, M. Ziebarth, M. Roschani and J. Beyerer, (2023). Deflectometry for specular surfaces: an overview. Advanced Optical Technologies. 12.

[2] W. YiNan, Z. Yun, G. Jia and Y. Z. Yu, "YOLOv5 Detection Algorithm of Steel Defects Based on Introducing Light Convolution Network and DIOU Function," 2023 IEEE 12th Data Driven Control and Learning Systems Conference (DDCLS), Xiangtan, China, 2023, pp. 118-122.

[3] Wang, J.; Su, S.; Wang, W.; Chu, C.; Jiang, L.; Ji, Y. An Object Detection Model for Paint Surface Detection Based on Improved YOLOv3. Machines 2022, 10, 261.

Development of a software application for heat pumps heat exchangers performance evaluation and analysis

Nuno Sousa [(a)], Vítor Costa [(a)], João Dias [(a)], Hugo Calisto[(b)], Mafalda Henriques[(b)]
(a) – TEMA, Department of Mechanical Engineering, University of Aveiro; (b) – Bosch Thermotechnology
Aveiro, Portugal
(a) – nsousa@ua.pt; joaomdias@ua.pt; v.costa@ua.pt; (b) – hugo.calisto@pt.bosch.com; mafalda.henriques@pt.bosch.com

***Abstract*— Heat pumps are a pivotal technology for the worldwide transition towards sustainable heating solutions. Their performance and potential for substantial reductions in greenhouse gases emissions make them crucial to mitigate the climate changes impacts [1].**

The development and optimization of the heat pump systems heavily depend on the detailed analysis and understanding of their heat exchangers performance. This work presents the development of a software application conceived, designed, and implemented to significantly enhance the evaluation and post-analysis processes of the heat pumps heat exchangers. This software application was conceived and implemented at the heat pumps experimental testing facilities of Bosch Thermotechnology in Aveiro. Bosch is a leading company in the heat pumps development, design, and manufacture, as part of its relevant role in the development, design, and manufacture of thermal engineering sustainable solutions.

The primary objective of the software application is to address and mitigate the challenges associated to the manual methods of heat pumps testing data handling and analysis. The previous approach often involved time-consuming exporting and analyzing test data processes, prone to errors, a hurdle that significantly delays the heat pumps systems development time-cycle. By automating the calculation of key performance parameters and facilitating visualization of data immediately after the test conclusion, the developed software application markedly reduces the time needed for data handling and analysis, thereby shortening the innovation time-cycle and avoiding error occurrence.

Moreover, the software application offers a comprehensive analysis toolkit beyond the basic heat transfer calculations. With the values of pressure and temperature measured in several points at the heat pumps, it can calculate the effectiveness, number of transfer units (NTU), and thermal conductance of the heat exchangers, focusing particularly on two-phase, superheated, and subcooled refrigerant fluid regions. Such detailed insights are crucial for the design and optimization of fin and tube and brazed plate heat exchangers, which are commonly used in air-water heat pump systems. The data used for the calculations are sourced from experimental tests on air-water heat pumps, according to the European norm 14511:2022 [2].

The software application additionally includes a user-friendly graphical interface that is accessible to the company lab users. It simplifies the process of transferring and exploring data, as well as evaluating and displaying the relevant performance indicators, extracting valuable information on the heat pumps heat exchangers performance.

It is important to note that the scope of this work is limited to the development of the software application itself and does not include modifications to the instrumentation hardware or the communications to data logger devices.

In conclusion, the conceived, developed and implemented software application offers valuable tools for the analysis of heat pumps heat exchangers performance, simplifying the complex and time consuming processes of data transfer and analysis, making them accessible for practical industry applications. It also prevents the appearance of errors associated with manual methods of data handling, while reducing the duration and difficulty of the evaluation process.

Keywords*— *heat pumps; heat exchangers; software application; heat exchangers performance; data transfer; data analysis and display.

ACKNOWLEGEMENTS

The present study was developed as a collaboration between the University of Aveiro and Bosch Thermotechnology, having the support of the projects UIDB/00481/2020 and UIDP/00481/2020. J.M.S. Dias acknowledges the support of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] IEA (2022), The Future of Heat Pumps, IEA, Paris https://www.iea.org/reports/the-future-of-heat-pumps, Licence: CC BY 4.0

[2] EN 14511:2022 + 14825:2022- Standards for Air conditioners all parts. (n.d.). https://www.en-standard.eu. https://www.en-standard.eu/en-14511-2022-14825-2022-standards-for-air-conditioners-all-parts/

Smart operations for wastewater treatment plants

Using machine learning models to enhance wastewater management

Sara Mota [(a),(b)], Antonio Andrade-Campos [(a),(b)]

(a) – Department of Mechanical Engineering, TEMA, University of Aveiro; (b) – Intelligent Systems Associate Laboratory (LASI)

(a) – Aveiro, Portugal; (b) – Guimarães, Portugal;

(a) – saramota@ua.pt; gilac@ua.pt

***Abstract*— Wastewater treatment plants (WWTPs) are essential infrastructures for managing sewage, although they face significant obstacles such as high energy usage, undue discharges, and the need to comply with stringent environmental standards. Studies have shown that these facilities contribute to 1% to 3% of the world's total energy use, consuming between 20 to 45 kWh per connected population equivalent (PE). More than half of this energy is used in the aerobic activated sludge process, especially in aeration, underscoring the process's intense energy demand [1].**

These challenges have been intensified with the progression of climate change, leading to potential public health risks due to inadequate sewage treatment, environmental concerns from high energy use, and the need for efficient operations to avoid undue discharges [2,3]. Therefore, it's increasingly urgent to improve wastewater treatment plants' efficiency. To boost both efficiency and sustainability, monitoring of these facilities is essential.

Leveraging sophisticated data analytics and predictive modeling, a digital twin facilitates improved decision-making, supports sustainability, and supports meeting environmental standards [4]. While numerous studies have effectively employed deep learning methods, there's still a largely untapped potential in integrating real-time data and using Internet of Things (IoT) technology for dynamic optimization. Typically, WWTPs rely on intermittent manual assessments of operational metrics, a method with limitations. This periodic approach might miss essential indicators due to timing and human mistakes, leading to results that diverge significantly from the true average and are inefficient in terms of time, especially regarding outcome delivery. IoT sensors can address these challenges by enabling continuous monitoring at specific points in the process, thereby identifying areas for potential efficiency improvements to lower wastewater management costs. Furthermore, these sensors can promptly alert management to issues as they arise, and not only during scheduled assessments, enhancing cost predictability and compliance assurance.

This work aims to significantly enhance the operational efficiency of WWTPs by integrating accurate digital twins with advanced data analytics. At the core of this work is the development of a digital twin that reflects the complete process of wastewater treatment, as well as its distinct stages, using real-time data from sensors across the facility.

Since the influent flow of a wastewater plant can be intermittent in time, Machine Learning (ML) algorithms like RNNs are chosen for their ability to handle time series information, enabling accurate predictions of the future states of the WWTP and allowing tactical adjustments to the operation.

Keywords*— *Wastewater; Digital Twin; Machine Learning; Cost reduction.

ACKNOWLEGEMENTS

This project has received funding from the Research Fund for Coal and Steel under grant agreement No 888153. This work is also supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] IWA Cluster for Resource Recovery from Water, “Circular Economy:Tapping the Power of Wastewater.” Accessed: Apr. 05, 2024. [Online]. Available: https://iwa-network.org/learn/circular-economy-tapping-the-power-of-wastewater

[2] P. Bugajski, E. Nowobilska-Majewska, and M. Majewski, “The Impact of Atmospheric Precipitation on Wastewater Volume Flowing into the Wastewater Treatment Plant in Nowy Targ (Poland) in Terms of Treatment Costs” Energies, Vol.14, Page 3806, June 2021.

[3] J. Hughes, K. Cowper-Heays, E. Olesson, R. Bell, and A. Stroombergen, “Impacts and implications of climate change on wastewater systems: A New Zealand perspective,” Climate Risk Management, vol. 31, p. 100262, January 2021.

[4] S. Zhou, S., Guo, W. Xu, B. Du, J. Liang, L. Wang & Y. Li, “Digital Twin-Based Pump Station Dynamic Scheduling for Energy-Saving Optimization in Water Supply System”. Water Resources Management. Feb. 2024.

Smart energy management system for e-bikes

Gândara, T. , Santos, J.P. [(a)] and Costa, V. [(a)]
(a) - TEMA - Centro de Tecnologia Mecânica e Automação, Departamento de Engenharia Mecânica, Universidade de Aveiro, 3810-193 Aveiro, Portugal
gandarat11@ua.pt , jps@ua.pt, v.costa@ua.pt

***Abstract*— As the electric vehicle industry becomes a crucial player in combating environmental pollution, effective energy management systems are essential to ensure battery safety, optimize energy utilization, and prolong vehicle lifespan [1]. With the increasing popularity of electric bicycles (e-bikes) as a sustainable mode of transportation, the demand for efficient energy management systems tailored to their specific needs has risen.**

The European e-bike market has seen significant growth in recent years, with projections indicating this trend will continue. In 2023, approximately 6.7 million e-bikes were sold in Europe, marking a considerable increase from previous years. This number is expected to continue rising, with forecasts suggesting that annual sales could reach around 13.5 million units by 2030 [2].

Safety has become a significant concern due to several lithium battery fires, thus urging ongoing security initiatives. At this moment, the systems available in the market are essentially black box closed systems, not open to implement different and innovative monitoring and control strategies and solutions. Some authors have focused on developing active cooling systems for electric motors and batteries [3][4]. This research work aims to develop an open smart energy management system integrated into a microcontroller for e-bikes, acting on the root of the problem by minimizing the heat generation through electrical current limitation.

The primary challenge addressed by this research work is the optimization of power consumption and battery temperature monitoring and control, to enhance the e-bike's autonomy while extending the battery's longevity. This problem is of high importance due to its direct impact on the usability and efficiency of e-bikes in real-world scenarios. Improving autonomy and battery lifespan not only enhances the user experience but also contributes to the overall sustainability of e-bikes transportation solutions.

The proposed solution entails the development of a novel electric motor controller leveraging a microcontroller architecture, tightly integrated with the e-bike's battery management system (BMS). This innovative approach allows seamless communication between the electric motor controller and the BMS, enabling real-time exchange of crucial data such as battery state of charge (SoC), temperature, voltage, and single battery cell information. By harnessing this bidirectional communication, the system can accurately regulate the electric motor power output based on instantaneous energy requirements and battery health metrics, including detecting any malfunction battery cells' degradation. Additionally, the microcontroller's computational capabilities allow the implementation of electrical current control algorithms for optimal energy use, thermal management, and predictive maintenance, ensuring both extended autonomy and prolonged battery lifespan while minimizing the risk of unexpected failures and risks.

The expected results of this research work include a significant improvement in e-bike autonomy and battery lifespan when comparing to conventional systems. Furthermore, this research lays the foundation for future advancements in smart energy management systems for e-bikes, contributing to the ongoing evolution of sustainable transportation technologies.

Keywords— e-bikes; energy management; energy efficiency; embedded control system; new and inovative control strategies.

ACKNOWLEGEMENTS

This work was developed in the scope of the Project AM2R – "Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas" [C644866475-00000012 – project n. 15], financed by PRR – Recovery and Resilience Plan under the Next Generation EU from the European Union, and by the projects UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020.

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] Dan D, Zhao Y, Wei M, Wang X, "Review of Thermal Management Technology for Electric Vehicles. Energies", 2023; 16(12):4693. DOI: 10.3390/en16124693.

[2] Mordor Intelligence. "Europe E-bike Market Size & Share Analysis - Industry Research Report - Growth Trends." 2023. Retrieved from: https://www.mordorintelligence.com/industry-reports/europe-e-bike-market.

[3] Chandra P S, Truong Q D, Somnath S, " Controller development of thermal management system for electric bikes", Energy Reports, Volume 8, 2022. DOI: 10.1016/j.egyr.2022.10.135

[4] Arrinda M, Vertiz G, Morel C, Hascoet N, Woltmann P, Sonnleitner A. "A Smart Control Strategy for a Battery Thermal Management System: Design, Validation and Implementation", 2022. Retrieved from: https://www.researchgate.net/publication/360860438.

Development of a real-time monitoring system for gas emissions from industrial chimneys

Diogo Torres [(a)], Sandra Rafael [(b)], André Quintã[(c,d,e)], João Dias[(a,d,e)]

(a) – Department of Mechanical Engineering (DEM), University of Aveiro; (b) – Institute of Environment and Development (IDAD); (c) School of Design, Management and Production Technologies Northern Aveiro (ESAN), University of Aveiro(d) Centre for Mechanical Technology and Automation (TEMA), University of Aveiro; (e) Intelligent Systems Associate Laboratory (LASI)

(a), (c), (d) - Aveiro, Portugal; (b) - Oliveira de Azeméis, Portugal; (e) - Guimarães, Portugal

(a) – dant@ua.pt

***Abstract* — Monitoring gaseous effluents is important to understand vertical concentration changes and the factors leading to these differences [1]. This continuous air quality monitoring is crucial for industries that produce substantial volumes of pollutants, such as chemical plants and factories. By tracking air quality, these sectors can verify their adherence to environmental standards and safeguard public well-being [2].**

The existing systems for monitoring gas emissions are not very effective and are accessible only at specific industrial chimney sites. This results in delays in the gathering of data and decision making. Industries also face challenges in accessing real-time data, which hinders their ability to make informed decisions and take necessary measures to reduce their environmental impact and comply with regulations.

This work aims to create an intelligent system for monitoring gas emissions from industrial chimneys in real-time. A graphical user interface is developed to enable access to emission data in real-time without being physically present at the chimney site, making it easier for industries to take informed actions and effective precautions.

The proposed approach involves gathering data from emission measurement equipment – FID (Flame Ionization Detector) - using a microcontroller, which then communicates via the MQTT (Message Queuing Telemetry Transport) protocol with a computer at the monitoring company (broker). The broker transmits the collected data to other devices equipped with real-time emission data visualization dashboard, and send it to a database managed by authorized entities for comprehensive management and analysis. It should be noted that this measurement equipment is used to measure VOCs – Volatile Organic Compounds, a common air pollutant emitted by several industries. The FID requires a strong and dependable system for converting and transmitting data due to its analog nature, underscoring the significance of creating this new smart and digital monitoring solution.

The implementation of this system will improve efficiency and accessibility in gas emission monitoring, facilitating timely decision-making and regulatory compliance. It will also reduce the weight and amount of equipment that has to be carried to the top of industrial chimneys 10 to 30 m above ground, preventing accidents with people and equipment, thus contributing to improving technicians working conditions. Furthermore, its scalability and potential for remote access offer significant benefits for environmental monitoring companies as well as industrial engineers, ultimately contributing to enhanced environmental stewardship and operational efficiency. This innovative approach has profound implications across various industries related to environmental and operational standards.

Keywords — Intelligent Systems; MQTT protocol; gaseous effluent; microcontroller; real time monitoring.

ACKNOWLEGEMENTS

The authors express appreciation for the support received from IDAD.

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] M. Väkevä, K. Hämeri, M. Kulmala, R. Lahdes, J. Ruuskanen, and T. Laitinen, "Street level versus rooftop concentrations of submicron aerosol particles and gaseous pollutants in an urban street canyon," Atmos Environ, vol. 33, no. 9, pp. 1385–1397, 1999, doi: https://doi.org/10.1016/S1352-2310(98)00349-5.

[2] OIZOM, "Importance of Real-Time Air Quality Monitoring and its Impact on Various Industries." Accessed: Apr. 15, 2024. [Online]. Available: https://www.linkedin.com/pulse/importance-real-time-air-quality-monitoring-its-impact/

Development of an Injection Mold Monitoring System

Helena Tavares [(a,b)], Rodrigo Bernardo [(a,b)], Mónica S.A.Oliveira [(a,b)] ,Jorge Ferreira [(a,b)],*
(a) - Centre for Mechanical Engineering and Automation (TEMA), Mechanical Engineering Department, University of Aveiro; (b) - Intelligent Systems Associate Laboratory (LASI)
(a) - Aveiro, Portugal; (b) – Guimarães, Portugal
(*) – hmtavares@ua.pt

***Abstract*— Nowadays, it's important to redesign products, technology, and processes in order to achieve greater environmental circularity in plastic manufacture through injection molding. Mold preparation with sensors—in-mold technology-- allowing the technical operator to interact directly in the process, can guarantee a greater productive performance 0. This study is fitted in the project OLIPush to develop a data acquisition system in which the main goal is to monitor essential variables such as pressure, temperature, and deflections remotely in real time from in-mold sensors and allow their storage in a database. Moreover, it aims to enable any user to remotely control this system via a web app.**

Initially, the system architecture was conceived, the hardware selected, its and an analysis of the system's fundamental needs from the user's perspective was carried out0. As in-mold sensing devices, a thermocouple was selected to detect the temperature of the mold, a PT (pressure and temperature) sensor was selected to register these variable at the most critical process point as identified by reviewing the literature0 (i.e as closest as possible to the gate) and a deflection sensor placed on the mold parting line. Furthermore, an Advantech Data Acquisition Module (ADAM) programmable data acquisition system was selected for data acquisition and transmission. The software developed for the monitoring system runs on a local personal computer (PC) and uses the Message Queuing Telemetry Transport (MQTT) protocol to send remote commands to ADAM, which responds with the current status of the analog inputs. A relational database stores the data, which is controlled by the MySQL server and uses Structured Query Language (SQL) for interaction. Software design tools such as use cases and mock-ups were used to define the user experience study. The web app was developed using specific open-source frameworks and application programming interfaces or APIs. As far as operation is concerned, a web interface has been developed using specific open-source frameworks and application programming interfaces or APIs. As it stands, the monitoring system can monitor and store all the data (data from the sensors and data from the mold and injection parameters entered by the user) and make queries to the database. From the tests carried out, it was found that the data acquisition system allows sampling periods of 50 ms

Keywords*— *in-mold sensors; injection molding; monitoring and control system

ACKNOWLEGEMENTS

The present study was developed in the scope of the Project"Agenda ILLIANCE"[C644919832-00000035|Project nº 22], financed by PRR—Plano de Recuperação e Resiliência under the Next Generation EU from the European Union, and supported by the projects: UIDB/00481/2020 and UIDP/00481/2020- Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] S. Kulkarni, "Robust Process Development and Scientific Molding Theory and Practice 2 nd Edition," 2017.

[2] T. Ageyeva, S. Horváth e J. G. Kovács, "In-mold sensors for injection molding:On theway to industry 4.0," Sensors (Switzerland), vol. 19, 16 ago. de 2019, issn:14248220. doi: 10.3390/s19163551.

[3] C. Rosen, Guide to Software Systems Development. Springer Nature Switzerland AG, 2020.

[4] P. N. L. Silva, "Monitorização de Variáveis de Processo e Estruturais de Ferramentas Moldantes, Dissertação de Mestrado, 2019.

[5] T. E. Gomes et al., "Development of an Open-Source Injection Mold Monitoring System," Sensors (Basel, Switzerland), vol. 23, 7 abr. de 2023, issn: 14248220. doi:10.3390/s23073569.

Digital Twins in the Energy Sector

Natacha Rosa [(a)], Sérgio M. O. Tavares [(a,b)]
(a) - TEMA—Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro; (b) - LASI - Intelligent Systems Associate Laboratory, Portugal
(c) - Aveiro, Portugal
(a) – narosa@ua.pt

***Abstract* — The digitalization of engineering has attracted huge attention in the last years due to its wide benefits in improving systems productivity and efficiency, as a potential means to reduce costs and time in developing new products and in enabling rapid innovation to respond to new market opportunities [1-3]. Supporting this trend is the forecast increase of 50% in global energy consumption by 2050 [4] and the introduction and progress of the digital twin tool, which is defined by E. Glaessgen and D. Stargel [5] as "an integrated multi-physics simulation of a system that employs existing physics-based models, sensors, and fleet history to reproduce the behaviour of its real counterpart.". In a more simplified description, digital twins can be defined as representations of an object or system and how it changes over time [6]. The evolution of this concept from an abstract theoretical idea into a fully developed technology promoted the application of digital twins to a vast variety of industrial sectors, including the energy domain [1, 7]. In the energy sector specifically, this technology empowers engineers to make data-driven system and network-level decisions towards the realization of the true potential of physical and digital convergence and the advancing of sustainability goals. Although the technology has been known for a long time in theory, its practical real-world applications have been so far limited, nevertheless with tremendous growth projections [8]. In this paper, we aim to better understand the role of this technology in shaping the future of the energy sector by shedding light on its integration within this domain, examining its application context, while also delving into the challenges encountered so far and the opportunities that this evolving topic offers. This review will allow for a reflection on the future trends of digital twins in the energy sector while also laying the groundwork for future research that aims at applying this tool in the energy sector field.**

Keywords*— *digital twin; energy sector; engineering digitalization

ACKNOWLEGEMENTS

The authors acknowledge the support of the Mobilizing Agenda for Business Innovation "ATE - Alliance for Energy Transition" reference BI/UI64/11373/2024 with the Center for Mechanical Technology and Automation (TEMA). The authors also acknowledge UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia; and CENTRO-01-0145-FEDER-022083 - Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund.

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] Semeraro, C., et al., "Digital twin application in energy storage: Trends and challenges," J. Energy Storage, 58, pp 106347, 2023.

[2] Qi, Q., et al., "Enabling technologies and tools for digital twin." J. Manuf. Syst.. 58, pp 3-21K. 2021.

[3] Rebentisch, E., Rhodes, D. H., Soares, A. L., Zimmerman, R. and Tavares, S. M. O. The digital twin as an enabler of digital transformation: a sociotechnical perspective. in 2021 IEEE 19th International Conference on Industrial Informatics (INDIN). 2021. IEEE.

[4] Ismail, F.B., Al-Faiz H., Hasini, H., Al-Bazi A. and Kazem, H.A. A comprehensive review of the dynamic applications of the digital twin technology across diverse energy sectors. Energy Strat. Rev., 2024. 52: p. 101334.

[5] Glaessgen, E. and D. Stargel. The digital twin paradigm for future NASA and US Air Force vehicles. in 53rd AIAA/ASME/ASCE/AHS/ASC structures, structural dynamics and materials conference 20th AIAA/ASME/AHS adaptive structures conference 14th AIAA. 2012.

[6] Solman, H., et al., "Digital twinning as an act of governance in the wind energy sector", Environ. Sci. Policy, 127, pp 272-279, 2022.

[7] Kumar, V., et al., "Digital transformation in industry: digital twins and new business models", Vol. 54. 2022: Springer Nature.

[8] Gourisetti, S.N.G., et al., "A theoretical open architecture framework and technology stack for digital twins in energy sector applications", Energies, 16(13), pp 4853, 2023.

Leak detection and localization in water supply systems

A comprehensive review of different techniques including machine learning models

Ana Luís Sousa [(a),(b)], António Andrade-Campos [(a),(b)], Eugénio Rocha [(c)]
(a) – Department of Mechanical Engineering, TEMA, University of Aveiro; (b) – Intelligent Systems Associate Laboratory (LASI); (c) Department of Mathematics, CIDMA, University of Aveiro
(a) – Aveiro, Portugal; (b) – Guimarães, Portugal; (c) – Aveiro, Portugal
(a) – ana.luis@ua.pt, gilac@ua.pt; (c) – eugenio@ua.pt

***Abstract*— Water leakage is a significant challenge faced by Water Supply Systems (WSS) companies due to its potential to remain undetected for long periods of time. The magnitude of water loss varies from 3% to over 50%, depending on system maintenance. Liemberger et al. [1] highlighted that the global volume of water loss per year is 126 billion cubic meters, equivalent to a loss of US$39 billion. Therefore, companies are seeking accurate approaches to detect and locate leaks quickly, reducing water losses and minimizing energy, environmental and economic consequences. To address this problem, some leakage management strategies have been developed, including preventive measures, systematic assessment protocols, regulatory frameworks, control measures, detection and localization techniques, and prompt repair initiatives [2, 3]. It is important to note that the detection and localization phase is crucial due to its complexity and critical role. Various techniques, including hardware- and software-based methods, are used. Hardware-based methods, such as acoustic, visual/radar, magnetic solutions, are site and knowledge dependent and can be very expensive [3]. Software-based methods can be used to detect leaks by inferring from pipeline parameters in real time and economically using digital twins and data analytics. However, their effectiveness depends on software calibration and accuracy [2, 4]. Machine learning (ML) models are valuable tools for detecting and localizing water leaks in water supply systems (WSS). These are particularly useful when considering physical laws and governing equations.**

This work aims to present an overview of detection and localization techniques used for water leaks in WSS and ML models. It includes relevant literature on physic-informed neural networks (PINN) applied to WSS [5, 6]. Additionally, it proposes a framework for detecting and localizing water leaks in WSS using an ML model and a highly-calibrated hydraulic simulator.

Keywords*— *Water Leakage; Water Supply Systems; Detection and Localization methods; Machine Learning; Physic Informed Neural Networks

ACKNOWLEGEMENTS

This work is supported by the doctoral grant (Ref. 2023.02917.BDANA) financed by the Portuguese Foundation for Science and Technology (FCT) and by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

3) Intelligent Systems
   b. Digital transformation

REFERENCES

[1] R. Liemberger and A. Wyatt, "Quantifying the global non-revenue water problem," Water Supply, vol. 19, no. 3, pp. 831–837, May 2019. [Online]. Available: https://iwaponline.com/ws/article/19/3/831/41417/Quantifying-the-global-nonrevenue-water-problem

[2] X. Wan, P. K. Kuhanestani, R. Farmani, and E. Keedwell, "Literature Review of Data Analytics for Leak Detection in Water Distribution Networks: A Focus on Pressure and Flow Smart Sensors," J. Water Resour. Plann. Manage., vol. 148, no. 10, p. 03122002, Oct. 2022. [Online]. Available: https://ascelibrary.org/doi/10.1061/%28ASCE%29WR.1943-5452.0001597

[3] D. Zaman, M. K. Tiwari, A. K. Gupta, and D. Sen, "A review of leakage detection strategies for pressurised pipeline in steady-state," Engineering Failure Analysis, vol. 109, p. 104264, Jan. 2020. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S1350630719300068

[4] A. Negm, X. Ma, and G. Aggidis, "Review of leakage detection in water distribution networks," IOP Conf. Ser.: Earth Environ. Sci., vol. 1136, no. 1, p. 012052, Jan. 2023. [Online]. Available: https://iopscience.iop.org/article/10.1088/1755-1315/1136/1/012052

[5] J. Ye, N. C. Do, W. Zeng, and M. Lambert, "Physics-informed neural networks for hydraulic transient analysis in pipeline systems," Water Research, vol. 221, p. 118828, Aug. 2022. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0043135422007771

[6] I. Daniel, J. Pesantez, S. Letzgus, M. A. Khaksar Fasaee, F. Alghamdi, E. Berglund, G. Mahinthakumar, and A. Cominola, "A Sequential Pressure-Based Algorithm for Data-Driven Leakage Identification and Model-Based Localization in Water Distribution Networks," Journal of Water Resources Planning and Management, vol. 148, no. 6, p. 04022025, Jun. 2022. [Online]. Available: https://ascelibrary.org/doi/10.1061/%28ASCE%29WR.1943-5452.0001535

Cutting tool's remaining useful life prediction through vibration signals analysis

Carolina Francisco [(a)], André Quintã [(b,c,d)], Jorge Ferreira [(a,c,d)], P. Soares [(e)]
(a) - Department of Mechanical Engineering, University of Aveiro; (b) - School of Design, Management and Production Technologies Northern Aveiro (ESAN), University of Aveiro; (c) Centre for Mechanical Technology and Automation (TEMA), University of Aveiro; (d) Intelligent Systems Associate Laboratory (LASI); (e) - Horse Aveiro
(a, c, e) – Aveiro, Portugal; (b) Oliveira de Azeméis, Portugal; (d) - Guimarães, Portugal
(a) – carolinaf@ua.pt

***Abstract*— Under the framework of Industry 4.0, machine tools should be able to perceive and make decisions independently [1]. However, the decision to replace cutting tools in machining processes still relies on human experience. Typically, a cutting tool is swapped out either when it reaches its predefined theoretical useful lifetime, when it starts producing not conforming parts or when it breaks while machining. Estimating the theoretically useful lifetime involves considering multiple factors intrinsic to the tool and machine characteristics, as well as the machining conditions and parameters [2].**

These replacement conditions often lead to inaccuracies in estimating tool life, resulting in some cases in the early replacement of a workable tool or in others in the late replacement of a worn tool, which may cause time and/or production loss [3]. Therefore, accurately determining the optimal time to replace a tool in machining is crucial for preventing unplanned downtime of the machine and maximizing the cutting tool's lifespan [2].

To address this challenge, efforts have been made to develop cutting tool monitoring systems that provide an estimation of the tool condition based on analytical or sensor-based models. These systems enable corrective action to avoid cutting tool failure and workpiece damage [4].

In this context, this work focuses on developing a cutting tool monitoring system that analyses vibration signals, collected in real-time, and relates them to the real tool breakage events to predict the practical end of the tool's life and anticipate potential failures, enabling decisions regarding tool replacement based on its actual wear state. The vibrational behaviour is learned and predicted by an LSTM model. Time and frequency domain features, representing the vibration behaviour, are extracted from the collected signals, and predicted signals. These features then serve as inputs to classification models, such as Decision Tree, SVM and Neural Networks, to define the tool's wear state, detect anomalies and ultimately determining its remaining useful life.

Keywords*— *Industry 4.0; Predictive Maitenence; Mechanical Vibrations; Signal Processing; Reamining Useful Life

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   c. Predictive algorithms

REFERENCES

[1] L. Bai, H. Liu, J. Zhang, and W. Zhao, "Real-time tool breakage monitoring based on dimensionless indicators under time-varying cutting conditions," Robot. Comput. Integr. Manuf., vol. 81, p. 102502, 2023, doi: https://doi.org/10.1016/j.rcim.2022.102502.

[2] S. Sayyad, S. Kumar, A. Bongale, K. Kotecha, and A. Abraham, "Remaining Useful-Life Prediction of the Milling Cutting Tool Using Time–Frequency-Based Features and Deep Learning Models," Sensors, vol. 23, no. 12, 2023, doi: 10.3390/s23125659.

[3] N. Ambhore, D. Kamble, S. Chinchanikar, and V. Wayal, "Tool Condition Monitoring System: A Review," Mater. Today Proc., vol. 2, no. 4, pp. 3419–3428, 2015, doi: https://doi.org/10.1016/j.matpr.2015.07.317.

[4] A. Mohamed, M. Hassan, R. M'Saoubi, and H. Attia, "Tool Condition Monitoring for High-Performance Machining Systems—A Review," Sensors, vol. 22, no. 6, 2022, doi: 10.3390/s22062206.

Extending IoT Networks with the Human Factor: An Example for an E-bike Scenario

(Emotion Sensitive Computing)

Syed Tahir Ali Shah[(a),], G. Constantinescu[(a)], A. Horovistiz[(a)], J. P. Santos[(a)], A. M. Bastos[(a)], M. I. Coelho[(a)], J. M. Fernandes[(b)] and M. S. Henriques[(c)]*
(a) TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, Campus Universitário de Santiago, 3810-193
(b) Department of Electronics, Telecommunications and Informatics (DETI) / IEETA / LASI, University of Aveiro, Campus Universitário de Santiago, 3810-193
(c)MHSi, Lda Factory Hub - Estrada Nacional 228, n.19 Covais, Coimbra, 3360-312, Travanca do Mondego
(a) Aveiro, Portugal; (b) Aveiro, Portugal; (c) Coimbra. Portugal
*syedtahiralishah@ua.pt

***Abstract*—The Internet of Things (IoT) is a rapidly expanding IT system approach implemented across various domains and functions with potential to impact our lives, from smart homes to personal healthcare and beyond [1]. The proliferation of sensors and IoT networks has facilitated the development and advancement of intelligent systems capable of adapting to human needs and environmental changes [2], in general, offering opportunities for improved longevity and quality of life [3].**

In this work, we propose integrating psychophysiological human factors into IoT networks to create a more personalised and responsive environment. We aim to achieve this by introducing a novel psychophysiology layer. This layer will enable the system to adapt to each individual user, sensing, responding, reacting, and providing recommendations based on the unique comprehensive surroundings, history, and psychophysiological state of each user. This aligns with the field of affective computing, which seeks to empower computer systems to better understand and react to human emotional status and improve the user experience, namely through emotion modulation [4].

Our proposed system takes a human-centric approach, striving to incorporate the psychological and emotional components of individuals into the overall system while relying on off-the-shelf solutions. By incorporating insights from affective computing and quantified self-concepts, we aim to devise a meta-decision layer that seamlessly integrates physical, environmental, traditional IoT domain, and psychophysiological data. The proposed approach involves creating a new level of decision-making that combines information from an individual's environment and psycho-physiology information (e.g. heart rate variability). Such integration would allow for an improved adapted experience for each user.

We propose a proof-of-concept system in an e-bike scenario. In the e-bike eco-commuting system, where a bike can be viewed as an IT/embedded system integrating sensors and actuators (namely bike status, location, and accelerator), our aim is to extend it to accommodate individual psychophysiology extracted markers, namely tiredness or attention levels, to customise the overall e-bike system from simple recommendation to adaptive reactivity to environment changes.

The concept of developing a meta-integrated layer that combines environment and psycho-physiology status either for pure reaction modulation of a system or for simple recommendations can be extended to scenarios other than e-bikes and can allow a flexible way of extending existing systems with more human-sensitive properties. Such a solution can also be useful for enhancing the comprehension of individual users' state and behavior patterns.

Keywords—IoT; Affective computing; Psychophysiological state; Integrated meta-decision layer.

ACKNOWLEDGEMENTS

This study was funded by the PRR – Plano de Recuperação e Resiliência and by the Next Generation EU funds at Universidade de Aveiro, through the scope of the Agenda for Business Innovation "AM2R - Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas" (Project no. 15 with the application C644866475-00000012) and UIDB/00127/2020, FCT/MCTES, COMPETE.

TOPIC

3) Intelligent Systems
   c. Predictive algorithms

REFERENCES

[1] M. Z. Ibrahim and R. Hassan, "The implementation of internet of things using test bed in the UKMNet environment," Asia Pac. J. Inf. Technol. Multimed, vol. 8, pp. 1–17, 2019

[2] Alazab, M., Gupta, M., & Ahmed, S. (2023). AIoT technologies and applications for smart environments. Institution of Engineering and Technology

[3] Jogdand, R. P., Singh, A., & Nagrathna, R. Role of Integrative Medicine in Oncology for longevity and Quality of life: A Case Report

[4] K. R. Scherer, T. Bänziger, and E. Roesch, A Blueprint for Affective Computing: A sourcebook and manual. Oxford university press, 2010

universidade de aveiro
theoria poiesis praxis
dem
department of mechanical engineering
tema
centre for mechanical technology and automation

Parameter identification of elastoplastic constitutive laws using machine learning techniques

João Marques [(a)], André Pereira [(b)], Pedro Prates [(a, c)]
(a) – TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, (b) CEMMPRE, ARISE, Department of Mechanical Engineering, University of Coimbra, (c) LASI – Intelligent Systems Associate Laboratory
(a) Aveiro, Portugal; (b) Coimbra, Portugal; (c) Guimarães, Portugal
(a) – gamboa.marques@ua.pt

***Abstract*— Accurate characterization of metal sheet plastic behavior is essential for reliable sheet metal forming simulations. To achieve this, certain aspects are considered, such as selecting constitutive models to describe material hardening and anisotropic behavior, as well as employing methods to identify constitutive parameters. Traditional methods for identifying constitutive parameters rely on standardized mechanical tests. While these tests are fundamental, they have limitations [1]. Sheet metal forming processes often involve complex loading conditions and non-homogeneous strain fields. Restricting characterization to tests with simple strain paths and uniform deformation might not fully capture the material's behavior encountered during manufacturing processes like sheet metal forming. This can lead to inaccurate material models and unreliable simulations. This necessity, coupled with advancements in computational capabilities, has motivated a shift towards utilizing Machine Learning (ML) and Artificial Intelligence (AI) to efficiently provide accurate solutions [2, 3].**

This work explores the construction of supervised regression models using the XGboost algorithm [4] to predict the material constitutive parameters that characterize the plastic behavior of metallic sheets. These predictive models are built upon a dataset populated with results from numerical simulations of biaxial tensile tests. Furthermore, cross-validation and sensitivity analyses are conducted, alongside a SHAP feature analysis. Additionally, data manipulation techniques are utilized to introduce noise and missing values in the dataset, aimed at evaluating the robustness of the predictive models.

Keywords*— *Parameter identification; Machine learning; Numerical simulation; Sheet metal forming

ACKNOWLEGEMENTS

This work is supported by the projects: UIDB/00481/2020 and UIDP/00481/2020 - Fundação para a Ciência e a Tecnologia, DOI 10.54499/UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020) and DOI 10.54499/UIDP/00481/2020 (https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   c. Predictive algorithms

REFERENCES

[1] P. A. Prates. “A new strategy for the simultaneous identification of constitutive laws parameters of metal sheets using a single test”. In: (Aug. 2014).

[2] A. Marques, A. Pereira, B. Ribeiro, P.A. Prates. “On the identification of material constitutive model parameters using machine learning algorithms”. In: vol. 926 KEM. Trans Tech Publications Ltd, 2022, pp. 2146–2153. ISBN: 9783035717594. DOI: 10.4028/p-5hf550.

[3] A Andrade-Campos. “On the inverse identification methods for forming plasticity models using full-field measurements”. In: vol. 1238. IOP Publishing, May 2022. DOI: 10.1088/1757-899X/1238/1/012059.

[4] T Chen and C Guestrin. “XGBoost: A scalable tree boosting system”. In: vol. 13-17-August-2016. Association for Computing Machinery, Aug. 2016, pp. 785–794. ISBN:9781450342322. DOI: 10.1145/2939672.2939785

Efficient fault classification in spark ignition testing of boilers: a two-step classification approach

José Cação [a ,b], José Santos [a, b] , Mário Antunes [c, d] and António Completo [a, b]

(a) TEMA - Centro de Tecnologia Mecânica e Automação, Departamento de Engenharia Mecânica, Universidade de Aveiro, 3810-193 Aveiro, Portugal

(b) LASI - Laboratório Associado de Sistemas Inteligentes, Guimarães, Portugal

(c) DETI - Departamento de Eletrónica, Telecomunicações e Informática, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

(d) *IT - Instituto de Telecomunicações, Aveiro, 3810-193 Aveiro, Portugal*

josemaria@ua.pt, jps@ua.pt, mario.antunes@ua.pt, completo@ua.pt

Abstract*—Recently, industry has undergone its 4th major revolution, marked by the integration and widespread adoption of multiple technologies, such as Machine Learning (ML), Internet of Things (IoT), and Artificial Intelligence (AI), culminating in the emergence of Industrial IoT (IIoT) [1, 2]. IIoT is characterized by the convergence of manufacturing processes, IoT devices, and ML processing techniques, enabling continuous monitoring and optimization of industrial processes. Particularly, ML data-driven techniques pose great potential within industrial data processing, having been successfully validated within numerous industrial domains and applications, like fault detection, equipment predictive maintenance, or cybersecurity [3-6]. This work discusses the development of an ML-based processing framework, designed for fault detection and identification, applied to a real-world industrial use case. The case study revolves around an innovative testing procedure, focused specifically on boiler spark ignition testing. The goal is to determine the occurrence and especially the quality of the spark's electric current, with ML processing potentially improving this detection, while also enabling the analysis of the gathered testing data. The proposed framework employs a dual-step classification strategy, initially determining the test outcomes by leveraging a binary classifier, and subsequently identifying the specific fault for unsuccessful tests, with a multi-label classifier focused solely on the anomalous instances. This method simplifies the overall classification task, excluding successful tests from the multi-label classification scenario, thereby concentrating on identifying failures. Preliminary results are encouraging. Eight classifiers were tested for both binary and multi-label stages. For binary classification, seven classifiers achieved perfect F1 scores, flawlessly distinguishing between normal and anomalous test outcomes. In the multi-label stage, four classifiers also yielded perfect F1 scores. Furthermore, these results proved better than a singular, multi-label approach comprising both normal and various anomalous fault labels. These findings underscore the efficiency and potential of the proposed two-step ML classification framework.

Keywords— Industrial IoT, Machine Learning, Anomaly Detection, Fault Classification

ACKNOWLEGEMENTS

This work was supported by the projects: "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46], financed by PRR—Plano de Recuperação e Resiliência under the Next Generation EU from the European Union; UIDB/00481/2020 and UIDP/00481/2020 financed by Fundação para a Ciência e a Tecnologia, (https://doi.org/10.54499/UIDB/00481/2020, https://doi.org/10.54499/UIDP/00481/2020).

TOPIC

3) Intelligent Systems
   d. Machine Learning

REFERENCES

[1] E. Sisinni, A. Saifullah, S. Han, U. Jennehag, and M. Gidlund, 'Industrial Internet of Things: Challenges, Opportunities, and Directions', IEEE Trans. Ind. Inf., vol. 14, no. 11, pp. 4724–4734, Nov. 2018, doi: 10.1109/TII.2018.2852491.

[2] D. G. S. Pivoto, L. F. F. De Almeida, R. Da Rosa Righi, J. J. P. C. Rodrigues, A. B. Lugli, and A. M. Alberti, 'Cyber-physical systems architectures for industrial internet of things applications in Industry 4.0: A literature review', Journal of Manufacturing Systems, vol. 58, pp. 176–192, Jan. 2021, doi: 10.1016/j.jmsy.2020.11.017.

[3] R. Marino, C. Wisultschew, A. Otero, J. M. Lanza-Gutierrez, J. Portilla, and E. de la Torre, 'A Machine-Learning-Based Distributed System for Fault Diagnosis With Scalable Detection Quality in Industrial IoT', IEEE INTERNET OF THINGS JOURNAL, vol. 8, no. 6, pp. 4339–4352, Mar. 2021, doi: 10.1109/JIOT.2020.3026211.

[4] M. Züfle, F. Moog, V. Lesch, C. Krupitzer, and S. Kounev, 'A machine learning-based workflow for automatic detection of anomalies in machine tools', ISA Transactions, vol. 125. pp. 445–458, 2022. doi: 10.1016/j.isatra.2021.07.010.

[5] R. H. Hadi, H. N. Hady, A. M. Hasan, A. Al-Jodah, and A. J. Humaidi, 'Improved Fault Classification for Predictive Maintenance in Industrial IoT Based on AutoML: A Case Study of Ball-Bearing Faults', Processes, vol. 11, no. 5. 2023. doi: 10.3390/pr11051507.

[6] Y. Jiang, P. Dai, P. Fang, R. Y. Zhong, and X. Cao, 'Electrical-STGCN: An Electrical Spatio-Temporal Graph Convolutional Network for Intelligent Predictive Maintenance', IEEE Transactions on Industrial Informatics, vol. 18, no. 12. pp. 8509–8518, 2022. doi: 10.1109/TII.2022.3143148.

Digital twins of power transformers: machine learning for fault assessment

Joaquim M. M. Duarte [(a,b)], Sérgio M. O. Tavares [(a,b)], Victor F. S. Neto [(a,b)]
(a) - TEMA - Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro; (b) - LASI - Intelligent Systems Associate Laboratory, Portugal
(a) - Aveiro, Portugal, (b) – Guimarães, Portugal
(a) – joaquimduarte@ua.pt

***Abstract*— A digital twin is a virtual model designed to accurately reflect a physical object or system. The concept originated in the early 2000s, with roots in the fields of aerospace and manufacturing. Today, it is applied in various industries, including healthcare, urban planning, automotive, and energy. The development of a digital twin involves several technologies: (i) IoT (Internet of Things): sensors and IoT devices collect real-time data from the physical world, which is essential for building and updating digital twins; (ii) Data analytics: this involves processing and analyzing the data collected to understand patterns and predict outcomes; (iii) Artificial intelligence: these technologies enable the digital twin to learn from data, predict future states, and simulate different scenarios [1], [2]. Digital twins of power transformers represent a significant technological advancement in the management and operation of electrical grids. These virtual models are digital replicas of physical transformers, designed to simulate, predict and optimize performance while enhancing reliability and efficiency. The primary application of digital twins in power transformers is predictive maintenance. By analyzing the operating conditions and predicting potential failures, this technology prevents unexpected outages and extends the life of the equipment [3]. Implementing machine learning in digital twins of power transformers for fault assessment is an innovative approach that offers several advantages such as: (i) accurate predictions; (ii) data efficiency and (iii) reduced computational costs [4], [5]. This conference will address the evolution and characterization of digital twins, focusing on current practices and strategic approaches for developing an accurate virtual model of a power transformer. Moreover, the conference will feature a comprehensive analysis of the current state-of-the-art in machine learning applications within the digital twins of power transformers, specifically for fault assessment.**

***Keywords*— digital twin; fault assessement; machine learning; physics-informed neural network (PINN); power transformer**

ACKNOWLEGEMENTS

This work is funded by the Recovery and Resilience Plan (PRR) and by European Funds NextGeneration EU under the Project "AET – Alliance for Energy Transition", nr. C644914747-00000023, investment project nr. 56, of the Incentive System "Agendas for Business Innovation" with the pplication 08/2024/BI/AgendasPRR and through the FCT – Fundação para a Ciência e a Tecnologia, I.P. and, when eligible, by COMPETE 2020 FEDER funds, under the Scientific Employment Stimulus – Individual Call (CEEC Individual) – CEECIND/04748/2017/CP1459/CT0048, and under the scope of the projects UIDB/04057/2020, UIDB/00481/2020 and UIDP/00481/2020, DOI 10.54499/UIDB/00481/2020 and DOI 10.54499/UIDP/00481/2020.

TOPIC

3) Intelligent Systems
   d. Machine Learning

REFERENCES

[1] K. Kukushkin, Y. Ryabov, and A. Borovkov, "Digital twins: a systematic literature review based on data analysis and topic modeling," Data (Basel), vol. 7, no. 12, pp. 173–173, Nov. 2022, doi: 10.3390/DATA7120173.

[2] Z. Liu, E. Blasch, M. Liao, C. Yang, K. Tsukada, and N. Meyendorf, "Digital twin for predictive maintenance," vol. 12489, pp. 1248907–1248907, Apr. 2023, doi: 10.1117/12.2660270.

[3] Yang et al., "State evaluation of power transformer based on digital twin," Proceedings - IEEE International Conference on Service Operations and Logistics, and Informatics 2019, SOLI 2019, pp. 230–235, Nov. 2019, doi: 10.1109/SOLI48380.2019.8955043.

[4] Z. Wang and H. Xu, "GCA-CNN based transformer digital twin model construction and fault diagnosis and condition evaluation analysis," Academic journal of computing & information science, vol. 6, no. 6, pp. 100–107, Jan. 2023, doi: 10.25236/AJCIS.2023.060616.

[5] W. Zhou et al., "Application of digital twin system in power transformer fault detection," 2023 IEEE 6th International Electrical and Energy Conference, CIEEC 2023, pp. 2123–2127, May 2023, doi: 10.1109/CIEEC58067.2023.10167284..

Combining multiple approaches for enhanced Remaining Useful Life Prediction

P. Nunes [(a)], E. Rocha [(b)], J.P. Santos [(a)]*

(a) – Department of Mechanical Engineering, Centre for Mechanical Technology & Automation, University of Aveiro; (b) – Department of Mathematics, Center of Research and Development in Mathematics and Applications, University of Aveiro

(a) - Aveiro, 3810-193, Portugal

* pnunes@ua.pt

***Abstract*— Predictive maintenance uses sensor data and data analysis techniques to forecast the remaining useful life (RUL) of industrial assets and optimize maintenance actions. Accurately forecasting the RUL is crucial for effective maintenance planning of various equipment, with aeronautic systems being one of the most widely studied fields. Numerous approaches in the literature, based on machine learning and deep learning, have demonstrated high accuracy in RUL estimation [1-2]. However, their complexity often renders them less interpretable, leading to their characterization as black boxes by maintenance practitioners, which hinders practical adoption.**

In this study, we report an innovative method that combines different approaches to enhance RUL predictions while improving model interpretability. Our method leverages a statistical approach grounded in traditional fault tree analysis [3-5] to facilitate qualitative analysis of failure modes and integrates a deep learning network to accuratly estimate the RUL of turbofan engines. By merging diverse methodologies, we aim to achieve a balanced approach that addresses the needs of maintenance practitioners and remains competitive in terms of accuracy when compared to state-of-the-art RUL estimation techniques. Experimental evaluations on benchmark datasets provided by NASA [6], demonstrate promising results, highlighting the potential of our method in real-world applications.

Keywords—Remaining useful life; machine learning; deep learning; statistical methods.

ACKNOWLEGEMENTS

The first author has a PhD grant supported FCT – Fundação para a Ciência e a Tecnologia, I.P. (ref. 2020.06926.BD). The second author was partially supported by the Center for Research and Development in Mathematics and Applications (CIDMA), through the Portuguese Foundation for Science and Technology, reference UIDB/04106/2022. The first and third authors acknowledge the University of Aveiro, FCT/MCTES for the financial support of TEMA research unit (FCT Ref. UIDB/00481/2020 & UIDP/00481/2020) and CENTRO01- 0145-FEDER-022083 - Regional Operational Program of the Center (Centro2020), within the scope of the Portugal 2020 Partnership Agreement, through the European Regional Development Fund.

TOPIC

3) Intelligent Systems
   e. Artificial Intelligence

REFERENCES

[1] Ma, Q., M. Zhang, Y. Xu, J. Song, and T. Zhang 2021, sep. Remaining Useful Life Estimation for Turbofan Engine with Transformer-based Deep Architecture. In 2021 26th International Conference on Automation and Computing (ICAC), pp. 1–6. IEEE.

[2] Li, Y., Y. Chen, Z. Hu, and H. Zhang. 2023. Remaining useful life prediction of aero-engine enabled by fusing knowledge and deep learning models. Reliability Engineering and System Safety 229 (May 2022): 108869.

[4] Nunes, P.; Rocha, E.; Santos, J.; Antunes, R. Predictive maintenance on injection molds by generalized fault trees and anomaly detection. Procedia Comput. Sci. 2023, 217, 1038–1047

[5] Nunes, P.; Rocha, E.; Neves, J.; Santos J., "Real-time condition-based maintenance of friction welding tools by generalized fault trees," in Springer, Cham, 2022, pp. 414–428. doi: 10.1007/978-3-031-20319-0_31.

[6] Saxena, A., K. Goebel, D. Simon, and N. Eklund 2008, oct. Damage propagation modeling for aircraft engine run-to-failure simulation. In 2008 International Conference on Prognostics and Health Management, pp. 1–9. IEEE.

TEchMA2024

Title:
TEchMA2024 – 7th International Conference on Technologies for the Wellbeing and Sustainable Manufacturing Solutions
Book of abstracts

Editors:
António Pereira, Paula Marques, Margarida Coelho, António Completo, Fernando Neto.

Organizing comittee:
Ana Horovistiz,
Ângela Semitela
Joana Mesquita-Guimarães
Luciana Rocha
Luís Pereira
Raul Simões

Publisher:
UA Editora, Universidade de Aveiro.

1st Edition – June 2024

ISBN: 978-972-789-919-7

DOI: https://doi.org/10.48528/mehv-z227

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/

This book is supported by the projects:
UIDB/00481/2020 and UIDP/00481/2020 - FCT - Fundação para a Ciência e a Tecnologia; and Project "Agenda ILLIANCE"; and Projet"AM2R – Agenda Mobilizadora para a inovação empresarial do setor das Duas Rodas"; and Project "Agenda ATE", financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

LASI Intelligent Systems Associate Laboratory
fct Fundação para a Ciência e a Tecnologia
PRR Plano de Recuperação e Resiliência
REPÚBLICA PORTUGUESA
Financiado pela União Europeia NextGenerationEU