laeta
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Book of Abstracts

6th Meeting of the Young Researchers of LAETA

6TH EJIL 2025
PORTO 27-28 OCTOBER

Edited by:
Ana Ramos, Margarida Machado, João Magrinho,
Ana Rita Amaral, Leandro Magalhães

INEGI – Instituto De Ciência e Inovação em Engenharia Mecânica e Industrial
Porto, Portugal

inegi | idMEC IST engenharia mecânica | AEROG Aeronautics and Astronautics Research Center | ADAI

Title:

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6th Meeting of the Young Researchers of LAETA

Edited by:

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First edition, **October 2025**

R. Dr. Roberto Frias, 400

4200-465 PORTO

WELCOME MESSAGE

6th Encontro de Jovens Investigadores do LAETA (EJIL 2025)

Porto, Portugal | 27–28 October 2025

Dear Participants,

It is with great pleasure that we welcome you to Porto for the 6th Encontro de Jovens Investigadores do LAETA (EJIL 2025). This event brings together young and experienced researchers from across the Associated Laboratory for Energy, Transports and Aeronautics (LAETA) and its partner institutions, fostering dialogue, collaboration, and innovation across diverse scientific fields.

Since its first edition, the EJIL has grown into a vibrant forum for the exchange of ideas, the presentation of emerging research, and the strengthening of bonds within our scientific community. The 2025 edition continues this tradition, offering an opportunity to share knowledge, inspire creativity, and encourage new collaborations that will drive future research and technological development.

This Book of Abstracts gathers the contributions presented during the conference, each abstract reflecting the dedication, curiosity, and scientific rigor of our participants, showcasing the vitality and diversity of research carried out within the LAETA network.

We would like to express our sincere gratitude to all authors, reviewers, keynote speakers, session chairs, and members of the organizing and scientific committees, whose efforts and commitment made this event possible.

We hope you find this collection both informative and inspiring, and that the discussions and connections made during EJIL 2025 will continue well beyond these two days. May this meeting in Porto strengthen the ties within our community and spark new ideas for the challenges ahead.

Welcome to EJIL 2025 — and enjoy the conference!

October 2025, Porto

With our best regards,

Ana Ramos *(Chair)*, INEGI
Margarida Machado, INEGI
João Magrinho, IST
Ana Rita Amaral, ADAI
Leandro Magalhães, AEROG

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CONFERENCE ORGANIZATION

Executive Committee

			
Ana Ramos *(Chair)* INEGI	João Magrinho IDMEC	Ana Rita Amaral ADAI	Leandro Magalhães AEROG

Scientific Committee

- Ana Ramos - INEGI
- João Magrinho - IDMEC
- Leandro Magalhães - AEROG
- Ana Amaral - ADAI
- Carlos Viegas - ADAI
- Vírginia Infante - IDMEC
- Pedro Camanho - INEGI
- Nuno Silvestre - IDMEC
- André Silva - AEROG
- Francisco Pires - INEGI
- Manuel Gameiro - ADAI
- Abílio de Jesus - INEGI
- António Andrade - IDMEC
- Mário Vaz - INEGI
- Adélio Gaspar - ADAI
- Vitor Leal - INEGI
- João Sousa - IDMEC
- Marco Parente - INEGI
- Duarte Valério - IDMEC
- Carlos Fonseca - INEGI
- Luís Reis - IDMEC
- Eliseu Monteiro - INEGI
- Sónia Simões - INEGI

Organizing Institutions

- INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering
- IDMEC, Institute of Mechanical Engineering
- ADAI, Association for the Development of Industrial Aerodynamics
- AEROG, Aeronautics and Astronautics Research Center
- FCT, Foundation for Science and Technology
- LAETA, Associate Laboratory of Energy, Transports and Aeronautics

CONFERENCE INFORMATION

Conference Venue

The 6th Meeting of the Young Researchers of LAETA (6EJIL) takes place at the Faculty of Engineering of the University of Porto (FEUP), located in R. Dr. Roberto Frias, s/n, 4200-465, Porto.

The Faculty of Engineering is the largest faculty of the University of Porto, with a privileged location in the Porto Innovation District.
With almost 10,000 students and more than 600 professors and researchers spread over six departments: Civil and Georesources Engineering, Electrical and Computer Engineering, Mechanical Engineering, Chemical and Biological Engineering, Industrial Engineering and Management and Informatics Engineering.

FEUP is located in a true innovation district, where the strong presence of engineering, health sciences and entrepreneurship is highly conducive to the innovation process. It is also home to the University of Porto Science and Technology Park (UPTEC), a fundamental structure for supporting the transfer of knowledge between the university and the market.

Life on Campus

- Virtual Tour Faculdade de Engenharia da Universidade do Porto

Safety: Information on safety procedures in the event of an unusual or dangerous situation on the Faculty of Engineering campus.

Dangerous situation
If you detect an unusual or potentially dangerous situation for people, equipment, and/or the environment, immediately alert the Security Officer, either in person or through the internal emergency number - #115 (from any internal extension within FEUP's network) or (+351) 91 22 333 77.
Safety information and procedures to be followed on the campus of the Faculty of Engineering, University of Porto.

Medical Emergency
In the event of sudden illness or an accident with victims, call 112 (National

Emergency Number) directly. The Emergency Central Operator will ask for information about the victim, which will enable a quick and effective response and the dispatch of appropriate emergency services. After calling 112, you should immediately contact the Security Officer - #115 (from any internal extension within FEUP's network) or (+351) 91 22 333 77 - so that they can take the necessary steps to send FEUP first responders to the location and facilitate access for the ambulance.

Safety team

The Safety Team is made up of staff from FEUP, the University of Porto, and other entities providing services at FEUP, all of whom are adequately trained and responsible for implementing and enforcing safety measures in line with the Internal Safety Plan. The team members are divided into various groups: Evacuation Teams, Fire Brigade, First Responders, and Technical Teams.

In case of an emergency or during a safety drill, follow the instructions of the Evacuation Coordinators and cooperate with the team - they will be identifiable by their vests.

Emergency Contacts

Emergency internal number: #115 (FEUP internal network), or (+351) 91 22 333 77

External entities

National Emergency Number: 112

Fire Brigade Battalion: (+351) 225 073 700

Porto Volunteer Firefighters: (+351) 226 151 800

Civil Protection (ANPC): (+351) 226 197 650

Poison Information Centre (CIAV): (+351) 800 250 250

SNS24: (+351) 808 24 24 24

PSP - Bom Pastor: (+351) 222 461 360

GNR - (+351) 223 399 600

Judicial Police (on-call): (+351) 225 088 644

Internal contacts

Management: 1622

Technical Maintenance and Environmental Services: 1500

Infodesk: 1400

FEUP First Aid (internal contacts)

Ana Carvalho (SICC): 4502
Daniel Reis (UPDigital): 3070
Fernando Silva (STMA): 4739
José Luís Moreira (DEQB): 3686
Maria Clara Ferreira (STMA): 4739
Nuno Pereira (STMA): 4739
Patrícia Pereira (DECG): 3784
Ramiro Soares (DEMec): 3122
Ricardo Barbosa (SEAG) 3521
Ricardo Silva (SDI): 3829
Rui Carvalho (DEEC): 3287

How to get to FEUP

- By metro: FEUP is served by three metro stations on line D (yellow) in zone C6. Line D (yellow) connects the University Centre with Gaia City Hall in about 15 minutes, passing through Trindade, where it connects with lines A (blue), B (red) and C (green). When you get off at Pólo Universitário station, turn left into Dr Manuel Pereira da Silva Street and, after passing the Paranhos cemetery, turn left into Rua do Dr Roberto Frias. Continue until you see FEUP on your right. Leaving the IPO, you should walk the whole length of Rua do Dr Plácido da Costa and cross Dr Roberto Frias Street. You are now in front of FEUP. Leaving the Hospital de São João, follow the ring road until the intersection with Rua do Dr Roberto Frias. Follow this street until it crosses Rua do Dr Plácido da Costa. FEUP is now on your left.

For more information, see Metro do Porto maps.

- By bus: there are four bus lines in the Faculty area: 204, 300, 301 and 803. Other STCP lines are also available from the Hospital de S. João, as well as regular routes to other cities. To choose the bus that best suits your needs, visit the following websites:

STCP Lines

STCP Plan your trip

- "MOVE-ME" App: To check the arrival time of your bus or metro, you can download the mobile app MOVE-ME.

- By car

The best way to find the Faculty of Engineering is to follow the signs to Hospital de São João. Here are the routes to FEUP from the main points of departure.

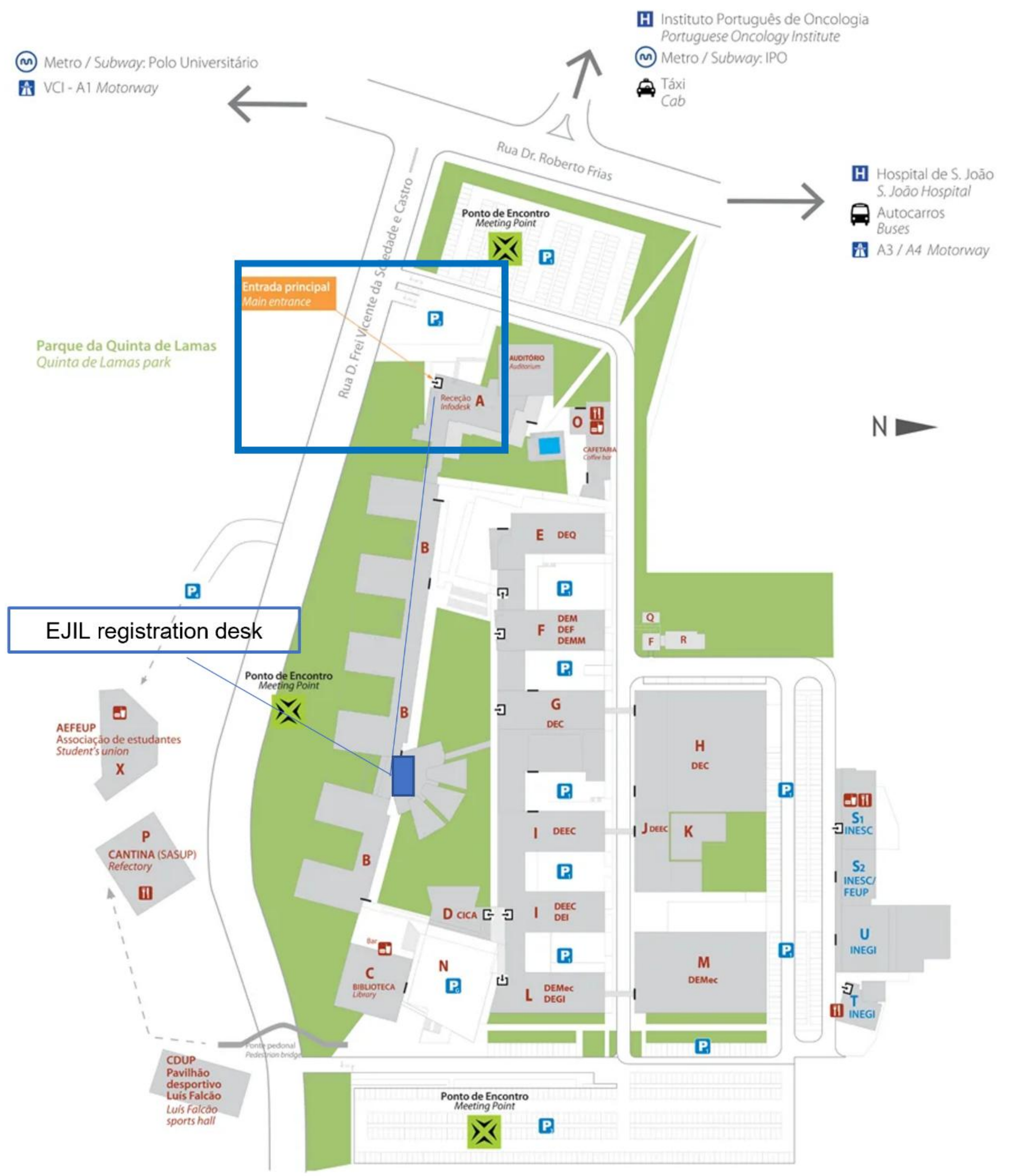
From Ermesinde, Gondomar and Valongo on the Circunvalação road (EN12):
Follow the EN12 until you see the Hospital de São João on your left. At the traffic lights with Rua Dr Roberto Frias, go straight ahead and keep to the left. At the next set of traffic lights, turn left into Rua António Bernardino Almeida (with the IPO on your right) and continue straight ahead until you reach the junction with Rua do Dr Plácido da Costa. Keep to the left until you reach the next junction, where you should turn left. Continue along this road until you come to another T-junction, where you should turn left. Continue until you reach the end of the road, which ends in Rua do Dr Roberto Frias, where you should turn left. Keep to the right until you reach the junction with Via Estruturante, where you should turn right.

From Maia and Matosinhos on the Circunvalação road (EN12):
Follow the EN12 until you see the IPO on your right. At the traffic lights, turn right into Rua António Bernardino Almeida (bypassing the IPO) and continue straight ahead until you reach the junction with Rua do Dr Plácido da Costa. Keep to the left until you reach the next junction, where you should turn left. Continue along this road until you reach another junction where you should turn left. Continue until you reach the end of the road that leads to Rua do Dr Roberto Frias, where you should turn left. Keep to the right until you reach the junction with Via Estruturante, where you should turn right.

- By train: If you arrive in the city of Porto by train, you have two options:

If you arrive at Campanhã station, take the metro and choose one of the following lines: A (blue), B (red), C (green), or E (purple). You will need to transfer at Trindade station and take the D (yellow) line. Follow the instructions provided under the "By metro" option.
If you arrive at S. Bento station, take the D (yellow) metro line and follow the instructions provided under the "By metro" option.
If you get off at the Campanhã Intermodal Terminal, you can use the new STCP line 404, with a direct connection to São João Hospital.

- By plane (Porto Airport): The fastest way to reach FEUP, if you don’t have your own vehicle waiting or don’t wish to take a taxi, is to take the metro on line E (purple). You will need to transfer at Trindade station and take line D (yellow). Then, follow the instructions provided under the "By metro" option.



If you arrive from the main entrance side, go up the stairs on your right hand-side and follow the long corridor (marked with B in the map), until you reach the so called FEUP lounge area, outside of which the registration desk will be located. There will be signs along the way and the registration desk will be easily identified.

Secretariat Opening Hours

- Monday, October 27: 09h00 – 18h00
- Tuesday, October 28: 8h30 – 17h30

Coffee Breaks and Lunches

The coffee breaks and lunches will take place at FEUP Lounge area, just next to the registration desk and will be available for all participants. A vegetarian option will also be provided. Please wear your conference badge.

Instructions for Presenters

Each Oral presentation will take 15 minutes: 12 minutes for presentation + 3 minutes for discussion.

• The files required for the presentation (PowerPoint or PDF) should be uploaded, and tested to ensure compatibility, during the coffee or lunch breaks before the beginning of the session. Please deliver your presentation in a USB key to the technical staff in the room.

• The lecture rooms contain a Windows PC, with Office and Acrobat PDF Reader, connected to a data projector. The use of personal computers is not recommended.

Wireless Internet Access

Participants without access to Eduroam should take the following steps:

Step 1 - Connect your mobile device to the UPorto wifi network.
Step 2 - Open a browser and enter the portal to the following credentials:

Username: LAETA2025
Password: Events2025%

SOCIAL PROGRAM

Conference Dinner

Conference Dinner – Monday, October 27, 20:00h

The conference dinner will take place at the Casa da Música restaurant, located in Av. da Boavista, 604-610, 4149-071, Porto, Portugal

GPS info:

41.158400, -8631000

+41° 9' 30.24" , -8° 37' 51.60"

The best way to reach Casa da Música is by:

- METRO

Lines A, B, C, E and F

Hours: 06:00 / 01:00 – Every day of the year

http://www.metrodoporto.pt

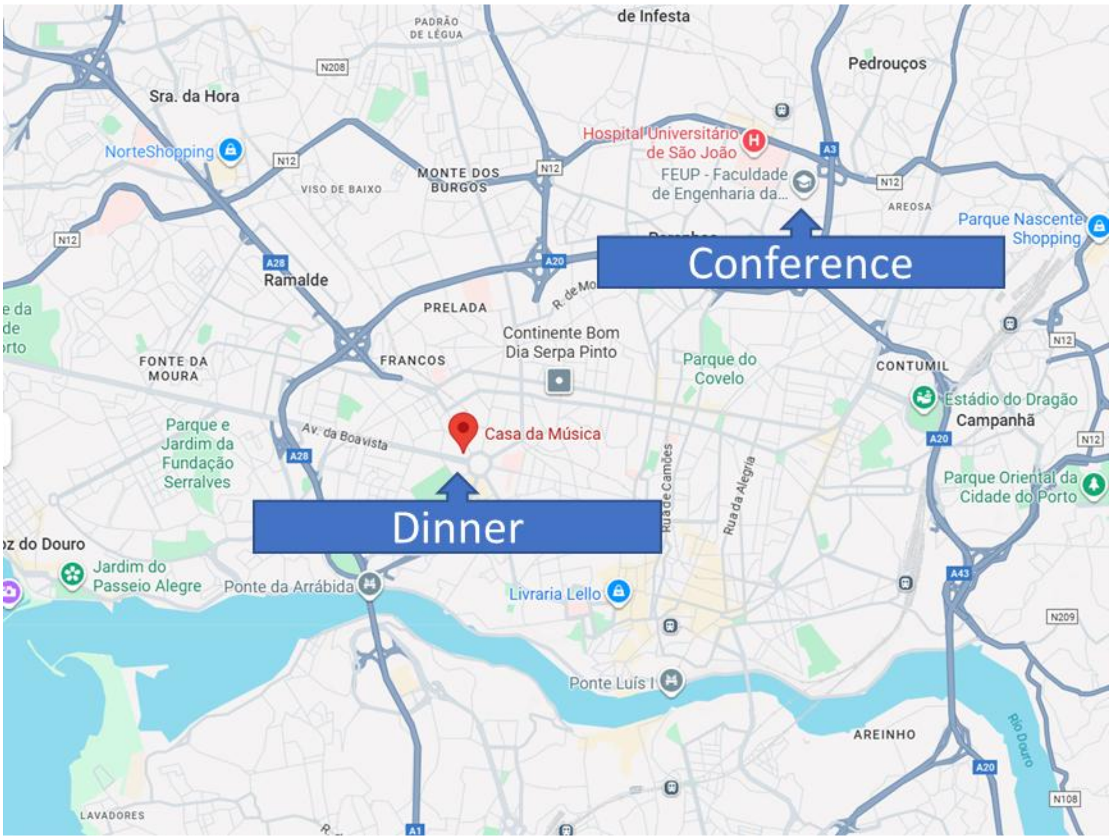
Metro do Porto / Maps and Timetables

- Bus

STCP – 201, 202, 203, 204, 208, 209, 303, 402, 501, 502, 503, 504, 507, 601, 803, 902, 903

www.stcp.pt

Porto Map


Conference
Dinner
Casa da Música
Hospital Universitário de São João
FEUP - Faculdade de Engenharia da...
Sra. da Hora
NorteShopping
Pedrouços
Ramalde
Parque Nascente Shopping
Continente Bom Dia Serpa Pinto
Parque do Covelo
Estádio do Dragão
Campanhã
Parque e Jardim da Fundação Serralves
Parque Oriental da Cidade do Porto
Jardim do Passeio Alegre
Ponte da Arrábida
Livraria Lello
Ponte Luís I
Av. da Boavista
Rua de Camões
Rua da Alegria
AREINHO
Rio Douro

SCIENTIFIC PROGRAM

Program Overview

	MONDAY, October 27	TUESDAY, October 28
09:00	REGISTRATION	KEYNOTE III
09:30		EES III / BIO II / ISC II
10:00	OPENING	
10:30	KEYNOTE I	
11:00	COFFEE BREAK	COFFEE BREAK
11:30	ISC I / SMS I / MMP I	EES IV / SMS III / MMP IV
12:00		
12:30		
13:00	LUNCH BREAK	LUNCH BREAK
13:30		
14:00	KEYNOTE II	KEYNOTE IV
14:30	BIO I / MMP II / EES I	SMS IV / BIO III
15:00		
15:30		
16:00	COFFEE BREAK	CLOSING
16:30	EES II / SMS II / MMP III	FAREWELL COFFEE
17:00		
17:30		
20:00	EJIL Dinner	

Detailed Program

6th EJIL 2025 — Detailed Programme — Porto, PORTUGAL

		MONDAY, October 27	Chair	Co-Chair	Local
09:00	10:00	REGISTRATION			Front Desk
10:00	10:30	OPENNING CEREMONY			B003
10:30	11:00	**KEYNOTE I** Virgínia Infante (IDMEC) *LAETA 2025-2029 Multiannual Programme .*	Ana Ramos (INEGI)		B003
11:00	11:30	COFFEE BREAK			Lounge
		PARALELL SESSIONS 1: ISC I, SMS I & MMP I			
11:30	13:00	**ISC I: Intelligent Systems & Control** Afonso Carvalho, *Ant colony Optimization applied to traditional and non-traditional warehouse layouts.* Miguel S. E. Martins, *A Digital Twin of the Ocean for the Azores Technological Free Zone.* Jhonny Rodrigues, *A Framework to Physics-Informed Neural Networks for thermal distribution in composite materials.* Filipe Santos, *Hidden Yet Exposed: Embeddings Encode Sensitive Information.* André R. Silva, *Preliminary Exploration of IK3070 Airfoil Dynamics Using Machine Learning.* João P. M. Oliveira, *Task-Parameterized Learning of Nonlinear Stable-Dynamical Systems.*	Duarte Valério (IDMEC)	Leandro Magalhães (AEROG)	B001
11:30	13:00	**SMS I: Structures & Mechanical Systems** Alexandre M. Palaio, *Improvement of a Fast Conceptual Rocket Design and Trajectory Optimization Framework with Hybrid Engine Model.* Erdem Dinler, *Unveiling Interrelations among Mechanical Properties of Polymer Composites.* Francisco Machado, *XFoil Neural Network: A Data-Driven Surrogate for 2D Airfoil Aerodynamic Analysis.* Francisco Portela, *New design of Bogie Y25 for Iberian Railway Gauge.* Vitor Silva, *Validation of Finite-Element Model of a MALE UAV Composite Wing with Experimental Static Bending Test.* Rui Coelho, *Composite Bayesian Optimisation for the Analysis and Design of Materials and Structures.*	Nuno Silvestre (IDMEC)	Carlos Viegas (ADAI)	B002
11:30	13:00	**MMP I: Materials & Manufacturing Processes** Bernardo L. Ribeiro, *Complex Concentrated Alloys as a Pathway to Next-Generation Lead-Free Brasses.* Daniel S. Correia, *Development of a unified specimen for direct generation of cohesive zone law data of adhesives.* Hélder Nunes, *Valorisation of Al-Si Secondary Alloys through Controlled Rare Earth Microalloying.* Vasco Rodrigues, *Debonding methods for electric vehicles battery packs.* Luis Piedra Marin, *Atomic-Scale Visualization of Moiré Patterns in Graphene Using TEM.* Duarte Cachulo, *Hydrogen environmental embrittlement in high-strength steels and their welds: from unified continuum-mechanics modeling to in-situ experimental characterization.*	Virgínia Infante (IDMEC)	Ana Ramos (INEGI)	B003
13:00	14:00	LUNCH BREAK			Lounge
14:00	14:30	**KEYNOTE II** André Silva (AEROG) *Open Science in the Research Process.*	Carlos Viegas (ADAI)		B003
		PARALELL SESSIONS 2: BIO I, MMP II & EES I			
14:30	16:00	**BIO I: Biomechanics** Carlos Quental, *Application of statistical shape models in the 3D reconstruction of the scapula and estimation of the glenohumeral joint center from limited data.* Margarida Neves, *A Geometry Based Simplified L4-S1 Finite Element Model for Topology Optimization of Spinal Cages.* Catarina Rocha, *Impact of Anterolateral Ligament Reconstruction on Knee Joint Pressure Following ACL Surgery.* Madalena Antunes, *A rotational driving constraint based on relative Euler parameters for redundancy-free multibody kinematics and dynamics.* Luís Pacheco, *Polynomial Surrogates for F-Actin Networks with Compliant Crosslinkers.* Sérgio B. Gonçalves, H-Move: *A Novel Multibody Tool Based on Fully Cartesian Coordinates and a Generic Rigid Body Formulation for Biomechanical System Analysis.*	Marco Parente (INEGI)	Leandro Magalhães (AEROG)	B001
14:30	16:00	**MMP II: Materials & Manufacturing Processes** João Magrinho, *Improving Local Formability in Sheet Injection Using Tailored Laser Heat Treatment.* Jorge Gil, *Predicting the fatigue life of 18Ni300 Maraging steel produced via directed energy deposition: an heuristic method.* Pedro Rosado, *Towards thin-walled construction by arc-based directed energy deposition via adaptive three-axis deposition strategies.* Fahad Zafar, *Characterization of Green Feedstock for Additive Manufacturing – Case study of a High-strength Aluminium alloy powder.* Tiago Oliveira, *Chemical-mechanical Devulcanization of SBR at Low Temperatures.* Alina Rodrigues, *An iterative design of experiments approach for 4D printing of PLA/EVA blends.*	Luís Reis (IDMEC)	Ana Ramos (INEGI)	B002
14:30	16:00	**EES I: Energy, Environment & Sustainability** James Ogundiran, *A Comparative Study on Indoor Air Quality, Air Stuffiness, and Air Change Rate in Classrooms with Different Ventilation Strategies.* Fátima Felgueiras, *Exploring the impact of indoor plants in modern offices on IEQ and workers' health, well-being and productivity.* Muhammad Tayyab Waheed, *IEQ in healthcare settings: Impact of continuous monitoring system on Infection risk, Thermal comfort and Energy Efficiency.* João Pedro Cardoso, *Modelling for net zero and positive energy districts: integrating new technological solutions.* Sofia Gonçalves, *Integrated Experimental–Modelling Framework for Colorific Energy Assessment in a Microwave Dual-Mode Cylindrical Cavity.* Bruno Cardoso, *The Afroenergy project: Empowering Mozambique for a just energy transition and improved living conditions.*	Vitor Leal (INEGI)	Carlos Viegas (ADAI)	B003
16:00	16:30	COFFEE BREAK			Lounge
		PARALELL SESSIONS 3: EES II, SMS II & MMP III			
16:30	18:00	**EES II: Energy, Environment & Sustainability** Beatriz Arouca Maia, *Design of Nanostructured LFP-Based Cathodes via Ultra-Low CNT Loading.* Joana Gouveia, *Driving Sustainability in Solid-State Battery Design: A Regulatory Blueprint for Ecodesign Excellence.* Tiago Fernandes, *Towards Lab-Scale Implementation of a Heat Pump–Organic Rankine Cycle Carnot Battery.* Manuela Baptista, *Anode-less solid-state batteries with a ferroelectric electrolyte: improved performance.* Sara Pinto, *European Regulations for the Digital Product Passport Implementation – A Transition to a Sustainable Economy.* Carlos Viegas, *Challenges and breakthroughs towards the automation and electrification of forestry heavy machines.*	Adélio Gaspar (ADAI)	Ana Ramos (INEGI)	B001
16:30	18:00	**SMS II: Structures & Mechanical Systems** António Carneiro, *A Unified Approach to Contact between Rough Surfaces: Contact Homogenisation with the Method of Multiscale Virtual Power.* Adriana Oliveira, *Wing Fatigue in the VHCF Regime: Numerical and Experimental Simulations.* Igor Lopes, *FE2 Modelling of Localisation with Second-Order Homogenisation with Emphasis on the Impact of the RVE Length and the Interplay between Mesh-Dependency Across Scales.* Paulo Ricardo Rocha, *Effect of the temporal discretization of contact forces on dynamic contact simulations using modified mass matrix.* Pedro Pinto, *Damage Modelling of Bolt-less HYPER Joints for Composite Connections.* Francisco Ricardo, *Axial Structural Stiffness Effects on Gear Dynamic Behaviour.*	André Silva (AEROG)	João Magrinho (IDMEC)	B002
16:30	18:00	**MMP III: Materials & manufacturing Processes** Matilde Martins, *Design, Manufacturing and Testing of an Innovative Ultrasonic Fatigue Specimen Composed of Cellular Structures.* Beatriz Sousa Monteiro, *Influence of Substrate Roughness and Coating Composition on HiPIMS-Coated SiAlON Cutting Tools.* Inês Almeida, *Formability limits in thin-walled tubes with square cross section and L-section profiles.* Rúben Costa, *Internal Hole Quality Assessment in the Drilling of Thin CFRP/Al Multi-Material Stacks.* João Viegas, *A new methodology for controlled thickness in deformation machining.* Francisco Bumba Paca, *Application of Stress scale factor approach to 316L stainless steel produced by powder bed fusion-laser beam.*	Abílio de Jesus (INEGI)	Leandro Magalhães (AEROG)	B003
20:00	23:00	EJIL 2025 DINNER			Casa da Música

Start	End	TUESDAY, October 28	Chair	Co-Chair	Local
09:00	09:30	**KEYNOTE III** Nuno Silvestre (IDMEC) *Wrinkling Mitigation in Solar Sails Through a Multiscale Approach.*	Leandro Magalhães (AEROG)		B003
09:30	11:00	**PARALELL SESSIONS 4: EES III, BIO II & ISC II**			
09:30	11:00	**EES III: Energy, Environment & Sustainability** Guilherme Grácio, *Optimization of a Hydrogen and Natural Gas Blending and Injection Station.* Miguel Coelho, *Techno-economic performance analysis and environmental impact assessment of transporting hydrogen through pipelines.* João Martins, *Effect of Turbulence Models on Hydrogen Injection Flow Dynamics in Natural Gas Pipelines.* Shiyuan Yang, *Intelligent identification of hydrogen trap information in temperature-programmed hydrogen desorption.* Sofia Nunes, *Evaluation of Different CO2 Capture Technologies - Life Cycle Assessment approach.* Maryam Karimi, *Investigating the Degradation Mechanisms of IrO2 Catalysts for PEM Water Electrolysis Using In-Situ Scanning Transmission Electron Microscopy.* Daniela Alves, *Moisture content of live and dead fine fuels and their relation to meteorological conditions and wildfire activity in the Central Region of Portugal (2000-2024).*	Manuel Gameiro (ADAI)	Ana Ramos (INEGI)	B003
09:30	11:00	**BIO II: Biomechanics** David Lopes, *Development of biomimetic polyvinyl alcohol/ polyethylene oxide/ lysine membranes functionalized with ibuprofen and salicylic acid for application in the regeneration of skin wounds.* Evangelia Antoniadi, *Development of Melt-Electrowritten Mesh Implants with Integrated Antistatic Properties for Hernia Repair.* Jhoselyn Acosta Yanez, *Production of 3D printed scaffolds coated with Gelatin and Tree tea oil for future application in bone tissue regeneration.* Nuno Miguel Ferreira, *Mechanical Suitability of Biodegradable Meshes in Pelvic Organ Prolapse Treatment.* Pedro Nogueira, *Experimental evaluation of intended decay of mechanical properties in iron lattice materials for biodegradable implants.* Sérgio B. Gonçalves, *On the Analysis of the Hemocompatibility of 3D-Printed ABS.*	Carlos Fonseca (INEGI)	João Magrinho (IDMEC)	B016
09:30	11:00	**ISC II: Intelligent Systems & Control** Armin Halicki, *A Requirements-Driven Control Architecture for Coordinated Robotic Ocean Surveys.* João Madeiras, *Quadrotor Trajectory Tracking: An Almost Global Full-State Solution.* Fábio Silva, *Benchmarking CNN Architectures for Robust Surface Defect Detection Across Multiple Domains.* Luís Martins, *Robust Global Exponential Attitude Tracking on SO (3) via Optimal MRP-Based Hybrid Feedback.* João Bogas, *Cost-Effective AUV Navigation.* Pedro Santos, *Trajectory Tracking Control for Sounding Rockets via Adaptive Feedback Linearization.*	João Sousa (IDMEC)	Leandro Magalhães (AEROG)	B015
11:00	11:30	**COFFEE BREAK**			Lounge
		PARALELL SESSIONS 5: EES IV, SMS III & MMP IV			
11:30	13:00	**EES IV: Energy, Environment & Sustainability** Ana Ramos, *Environmental and Economic Benchmarking of Municipal Waste Management through Waste-to-Energy Techniques.* Rui Silva, *Development of a HTHP design tool for industrial waste heat recovery system integrated with a two-phase variable geometry ejector and IHX using natural refrigerants.* Bruno Cardoso, *Understanding Energy Efficiency Barriers and Drivers in the Portuguese Water Sector: Upstream and Downstream Perspectives.* Mariam Sakhraji, *Trends, Gaps, and Methodological Challenges in Kinetic Modeling of Biomass Torrefaction: A Systematic TGA Review.* Filipe Neves, *Biomass combustion using a transient state approach.* Matheus Oliveira, *Valorization of Plastic-Biomass Mixtures in Co-Gasification: Simulation and Performance Assessment Using Aspen Plus®.* Diogo Oliveira, *Balancing beef: a physics-based multi objective framework for profit-sustainability trade-offs in beef production.*	Eliseu Monteiro (INEGI)	Carlos Viegas (ADAI)	B016
11:30	13:00	**SMS III: Structures & Mechanical Systems** Nuno Matos, *Automatic Aircraft Parametric Shape Generation for Design Optimization.* Júlia Ribeiro, *A Systematic Review of Cabin Noise Control Strategies for VTOL Aircraft.* Pedro Cardoso, *Low Reynolds UAV Airfoil Adjoint-Based Optimization with SA-BCM Transition Model.* Pedro Brito, *Aeroelastic simulation of torsional vibrations in a single-axis solar tracker.* Renato Morais, *Numerical Modeling of Oceanic Asteroid Impacts Using LSDYNA.* Pegah Mohammadpour, *Estimating Forest Canopy Fuel Parameters Using a Multi-Source LiDAR Approach for Central Portugal.*	Francisco Pires (INEGI)	Leandro Magalhães (AEROG)	B015
11:30	13:00	**MMP IV: Materials & manufacturing Processes** Ana Rita Carreiras, *Production of thermoplastic composites by pultrusion.* Arménio Correia, *Feasibility research on metal-polymer composite panels with integrated channels for thermal management systems.* Beatriz Pereira, *Assessment of embedded-element-based models for micro-scale simulation of fibre-reinforced composites.* Cláudia Mouro, *Sustainable valorization of wool keratin waste into functional nanofibers via electrospinning using deep eutectic solvents.* Ruben Pereira, *On the investigation of tailoring local permeabilities of ADFP thin-ply preforms on the enhancement of their VI processability.* Benjamin Andoh-Appiah, *Modular Onshore Power Supply Containers Made From Reused End-Of-Life Wind Turbine Blades.* Pedro Lopes, *Microstructural and Physical Characterization of Atomet 195 SP Iron Powder for Laser Powder Bed Fusion.*	Sónia Simões (INEGI)	João Magrinho (IDMEC)	B003
13:00	14:00	**LUNCH BREAK**			Lounge
14:00	14:30	**KEYNOTE IV** Pedro Camanho, *How to write competitive research proposals - a personal view*	João Magrinho (IDMEC)		B003
		PARALELL SESSIONS 6: SMS IV & BIO III			
14:30	16:00	**SMS IV: Structures & Mechanical Systems** João Marafona, *How Gear Mesh Stiffness Asymmetry Influences Gear Behaviour.* Rita Dantas, *An analysis of the frequency effect in fatigue data: from uniaxial to multiaxial loading.* Pedro Marques, *Modified gears for constant mesh stiffness.* Abhishek S. Bhadouria, *Identifying the most appropiate lifetime variable for maintenance freight wagon wheelsets.* Stéphane Portron, *Investigating Gear Mesh Stiffness in High Contact Ratio Plastic Gears.* Tiago Sabino, *Toward modeling transfer film evolution in tribological contacts: A preliminary computational approach.*	António Andrade (IDMEC)	Leandro Magalhães (AEROG)	B003
14:30	16:00	**BIO III: Biomechanics** Micaela Cunha Rodrigues, *Association between Maximum Handgrip Strength and Force-Time Curve Indicators from Handgrip Digital Dynamometry with Undernutrition Risk in a Multicentre Cross-Sectional Sample of Heart Failure Outpatients - The NUTRIC Project.* Rita Moura, *Modeling the Dynamics of Vacuum-Assisted Delivery: A Biomechanical Study.* Joana Cerqueira, *Diagnosis, Monitoring, and Functional Recovery of Knee Musculoskeletal Injuries.* Flávio L. Lázaro, *Identifying Human Factors in Aviation Accidents with Natural Language Processing and Machine Learning Models.* Vasco Reis, *Immersive Tools for The Future of Mining Engineering Students.*	Mário Vaz (INEGI)	João Magrinho (IDMEC)	B015
16:00	16:30	**CLOSING CEREMONY**			B003
16:30	17:30	**FAREWELL COFFEE**			Lounge

ABSTRACTS

ISC I: Intelligent Systems and Control

Ant colony Optimization applied to traditional and non-traditional warehouse layouts

Afonso Carvalho
INEGI

This article will propose a method for finding which configuration of warehouse layout is best to facilitate the picking operation inside the warehouse. For the gathering of results a Breadth-First Search (BFS) algorithm was designed to find the distance between the products to be picked, and an Ant Colony Optimization (ACO) algorithm was used to determine the shortest route to pick these products, the location of the products is random, and the algorithm is runned with different setups for both the traditional warehouse layout and non-traditional warehouse layout. Results show that the average distance for picking is lower in traditional warehouses than in non-traditional warehouses.

A Digital Twin of the Ocean for the Azores Technological Free Zone

Miguel S. E. Martins[1]; James Gillar[2]; Umut Firat[2]; Jorge Fontes[3]; Luís Veloso[4]; Ana Rodrigues[5]; Maria Magalhães[6]; Telmo Dias[7]; Susana Vieira[1]; João M. C. Sousa[1]; Giacomo Dieci[2]; Guilherme Vaz[2]

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The Azores Technological Free Zone (ZLT) was created in the Azores archipelago, a geographical area designed to foster innovation and technological development by allowing testing and experimentation in real or quasi-real environments. The work to develop will combine sensor oceanographic data, numerical modelling tools and AI-based analysis to create a Digital Twin of the area. It will be important tool to measure, predict and react to changes in marine environments since it will receive and display real-time data. Data sources include multiple underwater sensors, passive acoustic sensors, metocean buoys, bottom mounted sensors and animal-born sensors. Camera feeds and spectrograms will be used, augmented by artificial intelligence methods. To accurately predict the behaviour of ocean dynamics, numerical oceanographic, acoustics propagation and computational fluid dynamic models will be used. This and the existing data will allow for surrogate models to be developed, to efficiently test what-if predictive scenarios based on live data. To aggregate all data, and run computational and AI models, the well-known European Digital Twin of the Ocean (EDITO) will be used. This also allows for the data gathered to be uploaded to the Portuguese National Oceanographic Data Centre (NODC-PT), which is interoperable with higher hierarchical marine spatial data infrastructures like EMODnet. The consortium of the DATAz project consists of multi-disciplinary partners both from public and private institutions: IDMEC (Instituto Superior Técnico, Universidade Técnica de Lisboa)), blueOASIS (Portuguese ocean deeptech SME), Okeanos (University of the Azores), ADAFMA (Maritime School of the Azores), IH (Hydrographic Institute from the Navy), CEOM (Navy Experimental centre) and the DRPM (Direção Regional de Políticas Marítimas). The proposed Digital Twin prototype will use the ZLT as a use case to improve ocean knowledge in this specific region, particularly regarding environmental and biodiversity protection, sea state and climate change monitoring, and human impacts assessment, promoting the sustainable and safe use of the sea.

A Framework to Physics-Informed Neural Networks for thermal distribution in composite materials

Jhonny Rodrigues
INEGI

In search of improving the manufacturing process of composite materials that highly depend on thermal phenomena, a significant challenge is to know the temperature distribution of the structure in real time. The main goal of this monitoring is to ensure that the correct temperature values are achieved, to obtain proper adhesion between ply layers, and to determine the degree of curing for a thermoset composite matrix. The most common and direct strategy is placing sensors distributed all over the manufacturing structure. Although this strategy gives good results, it may produce superficial defects that may compromise the mechanical performance of the structure or its aesthetics; internal sensors are not allowed to also interfere with the mechanical performance by creating significant structural defects, leaving the internal temperatures unknown, and having to rely on simulations to better understand those states.

To address the problem of not knowing the internal thermal states of a composite material while manufacturing, researchers focused their attention on simulating a priori the manufacturing process according to initial and boundary conditions. These simulations tend to be demanding from a computational point of view and don't allow any real-time compensation. Another method to estimate the internal temperature distribution that has been in development in the last years involves the use of physics-informed neural networks [1].

This work proposes a framework to create physics-informed neural networks for thermal distribution in composite materials, taking into account different types of boundary conditions for geometries with different orders of magnitude in a dimensionless manner. The boundary conditions are also mathematically manipulated, converting the original boundary conditions into dimensionless values that correspond with the physics of the problem being studied.

The trained neural networks can reproduce the thermal distribution inside a composite material with an error lower than 5% compared with a finite element method.

Although this proposed framework tests multiple network architecture configurations, it converges into a solution that estimates the internal temperature distribution with an acceptable error, allowing the computation of internal thermal states faster than its numerical counterpart.

[1] Nelson D. Gonçalves and Jhonny de Sá Rodrigues. "Heat Conduction Control Using Deep Q-Learning Approach with Physics-Informed Neural Networks". In: Metrology 4.3 (Sept. 2024), pp. 489–505. ISSN: 2673-8244. DOI: 10.3390/metrology4030030

Hidden Yet Exposed: Embeddings Encode Sensitive Information

Filipe Santos
IDMEC

Purpose: This study investigates the extent to which demographic information (age, sex, ethnicity, and insurance type) is encoded in vector embeddings derived from chest radiographs in the MIMIC-CXR and CheXpert datasets.

Materials and Methods: We used three different embedding models, CXR Foundation, MedCLIP, and BiomedCLIP, to generate vector embeddings from chest radiographs in the MIMIC-CXR dataset. Statistical analyses, namely Kolmogorov-Smirnov tests and Mann-Whitney U-tests, were conducted to assess how demographic information is encoded in the embedding space. Additionally, machine learning models were trained to predict demographic attributes from these embeddings. The predictability of demographic information was evaluated using ROC-AUC and other performance metrics. Furthermore, to measure redundancy of the demographic encoding, the top features relevant to demographic predictions were modified, and the models predictive performance was re-evaluated after retraining.

Results: Demographic information was encoded in the vast majority of features across all studied embedding spaces. Depending on the demographic groups and embedding space used results range from 60% to 100% of the features. The models trained to predict demographic variables reveal that this information can be easily retrieved. Modifications to key features in the embeddings resulted in a small decline in predictive performance, suggesting that demographic information is redundantly encoded.

Conclusion: The study demonstrates that demographic information is embedded in chest radiograph-derived embeddings, raising concerns about potential biases in clinical applications. Future research should focus on disentangling demographic information from disease-specific features in embeddings to minimize potential biases and ensure fairness in predictive models used in healthcare.

Preliminary Exploration of IK3070 Airfoil Dynamics Using Machine Learning

Emanuel A. R. Camacho[1]; Flávio D. Marques[2]; André R. Silva[1]
[1]AEROG; [2]Universidade de São Paulo (EESC)

This study presents a recurrent neural network (RNN) approach to predict the unsteady aerodynamic loads of a novel airfoil geometry, the IK3070, which features three independent parts obtained by the segmentation of the commonly known NACA0012 profile. This new system originates from a modification to the widely used NACA0012, initially with the purpose of improving the propulsive capabilities of flapping airfoils. This modification, called the IK30 airfoil, divided the airfoil into two parts that could be actuated independently, thus introducing the concept of dynamic curvature. Such a system was later tested in dynamic stall conditions, at a much higher Reynolds number, indicating tremendous potential. Building upon this mechanism and the advantages that dynamic curvature opened up, this paper extends this design, dividing the airfoil once again. A large dataset was generated using an unsteady panel method, allowing the geometry to pass through a wide range of pitching kinematics at a fixed Reynolds number. Rather than analyzing individual and traditional kinematics, the approach involves perturbing each section of the airfoil randomly within defined limits for a set period of time. This method enables the collection of data where each section undergoes different regimes over time, supplying the neural network training process with ample information to understand the IK3070 dynamics. The RNN was trained to predict time-dependent drag, lift, and moment coefficients from the kinematic combinations of each airfoil segment. Results show that the RNN presents high predictive accuracy for both training and test data, capturing nonlinear aerodynamic phenomena. During testing, the model generalized well to periodic motions that were not present in the training set, offering a robust model for potential future real-time applications. While the current work is limited to moderate angles of attack and potential flow conditions, it establishes a foundation for future integration of experimental data and high-fidelity data from simulations to tackle more complex aerodynamic regimes, including dynamic stall.

Task-Parameterized Learning of Nonlinear Stable-Dynamical Systems

João Paulo Mendes Oliveira[1]; Niels Dehio[2]; Jorge Manuel Mateus Martins[1]
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Industrial robotics research focuses on intuitive interfaces like Learning from Demonstration (LfD) to enable nonexperts to program robots quickly. Operators demonstrate tasks and machine learning processes this data to generate robot motion, avoiding complex programming. Modern LfD requires few demonstrations (e.g., via hand guidance or teleoperation). Demonstration data capture robot states and their change, forming a regression problem to estimate system dynamics. Basic LfD replicates trajectories; Task-Parameterized (TP) LfD handles variable scenarios (e.g., different start/goal/obstacle positions) by building a "Memory of Motion" from demonstrations under various conditions. This allows autonomous motion generation for perceived scenarios.

The literature on LfD provides us with a vast collection of function models encoding different properties. Traditionally, the formulation of Dynamic Motion Primitives (DMPs) paved the way toward motion learning. Note that DMPs are inherently stable due to their underlying model structure and can be extended to encode parameterized skills. Global asymptotic stability (GAS) as introduced by Lyapunov is a favorable property when robot controllers are implemented.

Related work distinguishes between state and time-dependent systems. We favor state-dependent systems that correct for perturbations by default, which is not trivially achieved with time-dependent systems. Different approaches have been proposed to tackle TP-LfD for dynamical systems, however nontrivial GAS constraints render the underlying optimization procedures untractable. This research aims to combine two features: stability (Global Asymptotic Stability - GAS) and task-parameterization. By projecting GAS constraints into alternative representations (through bijective mappings) we obtain convex constraints that can be used with traditional quadratic programming optimizer's.

This framework results in a task-parameterized autonomous learning routine that: 1) is efficient procedure to learn the proposed constrained model-parameters; 2) guarantees that any generated trajectory starts precisely in the given start frame and ends precisely in the given target frame, while capturing alternative strategies to avoid an obstacle specified by an obstacle frame; 3) enables to react to and correct for disturbances through its formulation as a parameterized dynamical system.

Extensive simulations and real-robot experiments validate our approach. Our novel framework empowers a novice user to teach parameterized motion primitives with GAS while avoiding obstacles in variable environments. The autonomous robot quickly learns the underlying motion pattern, requiring only a handful of demonstrations. The final system replicates the demonstrated trajectories and is capable of extrapolating to new scenarios.

SMS I: Structures and Mechanical Systems

Improvement of a Fast Conceptual Rocket Design and Trajectory Optimization Framework with Hybrid Engine Model

Alexandre M. Palaio[1]; André C. Marta[2]; Alain de Souza[2]

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The extreme operating conditions, highly demanding mission requirements, and intricate and tightly coupled nature of the underlying physical phenomena represent only a few of the challenges engineers must address in the development of aerospace technological solutions. In such an unforgiving domain, the optimization of resources is absolutely vital to extract the best performance with minimal cost and time. To that end, a multidisciplinary design with trajectory optimization framework geared for the preliminary design of rockets optimization, comprised of six low-fidelity disciplinary models -- models of mass and sizing, flight dynamics, aerodynamics, solid-propellant propulsion, structural, and atmosphere -- coupled using a Multidisciplinary Design Feasible (MDF) architecture, had been previously developed and demonstrated. The design optimization algorithm is gradient-based for reduced computational cost, and the trajectory optimization uses a Gauss-Lobatto pseudo-spectral method due to its efficiency in solving continuous nonlinear constrained optimal control problems, high accuracy, and low computational cost. In order to further expand the capabilities of the integrated design framework, this work focuses on development of a new propulsion model to handle hybrid liquid-solid propellant engines. The new capability is demonstrated in the design of a sounding rocket, considering two engine cases -- solid propellant and hybrid engines.

The resulting distinct designs for a set of different mission requirements, comprising variations of peak altitude and payload mass, are compared and discussed in terms of overall rocket sizing. The results show the framework's potential to efficiently handle complex rocket design problems with different engine solutions, while offering valuable design insight in terms of mission requirements at a relatively low computational cost at early development stages. Given the framework modularity, continued effort for the expansion of its capabilities is expected to further extend its applicability to other aerospace solutions, such as multi-stage configurations or other propulsion systems.

Unveiling Interrelations among Mechanical Properties of Polymer Composites

Erdem Dinler[1]; Igor André Rodrigues Lopes[1]; Carolina Furtado[2]; Pedro Camanho[2]

[1]INEGI; [2]FEUP

The meso-scale numerical simulations of carbon-epoxy coupons generally use a ply-by-ply discretisation method, requiring a multitude of material properties to define each ply's anisotropic elastic and failure characteristics. This study creates an efficient method for quickly estimating meso-scale parameters with minimal experimental data by using the observed relationships between different elastic and intralaminar properties of carbon-epoxy systems.

A novel invariant-based model estimates unidirectional carbon fibre-reinforced polymer (CFRP) lamina fracture properties, including ultimate strengths in longitudinal, transverse, and shear directions, as well as intralaminar longitudinal fracture toughness. Developed through an extensive literature review of carbon/epoxy systems, the model significantly decreases experimental testing requirements by utilising the Tsai modulus to apply stiffness properties for estimating strength and toughness.

Finite element analyses of open-hole tensile specimens validate the close alignment between experimental and predicted results. The model's integrated approach allows precise meso-scale simulations with limited experimental data, improving material characterisation procedures in aerospace applications.

XFoil Neural Network: A Data-Driven Surrogate for 2D Airfoil Aerodynamic Analysis

Francisco Machado[1]; André C. Marta[2]; Luís Eça[2]
[1]Tekever, IDMEC; [2]IDMEC

Recent advances in physics-informed and physics-aware machine learning have shown great promise in modeling complex physical systems with higher efficiency. These approaches aim to bridge the gap between purely data-driven methods and traditional physics-based solvers by integrating physical principles either through explicit constraints, informed architectures, or training on simulation data. Motivated by this progress, this work introduces XFoil Neural Network, a lightweight deep learning surrogate model trained on XFoil simulations to replicate two-dimensional aerodynamic performance and flow characteristics of airfoils. The model receives as input a compact airfoil parameterization, angle of attack, and Reynolds number, and outputs global aerodynamic coefficients — lift, drag, and pitching moment — as well as local flow features including pressure coefficient (Cp) distribution, boundary layer shape factor profile,and transition location on the upper and lower surfaces. The objective is to evaluate the ability of a compact neural network architecture to generalize across a wide variety of airfoil geometries and flow conditions. In addition to assessing predictive accuracy, this study explores the importance of training data quality and hyperparameter tuning in producing physically plausible and reliable results. The model demonstrates strong agreement with XFoil simulations across a range of operating conditions, suggesting its potential for use in rapid design iteration or optimization cycles.

New design of Bogie Y25 for Iberian Railway Gauge

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The European sustainability program "Green Deal" makes a significant investment in the railway sector. Regarding freight transport, the EU aims to increase rail transport by 50% by 2030 and double it by 2050. However, freight railway lacked of innovation over past decades. Lightweight Design and the higher payload improve railways competitiveness and reduce operative costs. Therefore, design new railway bogies is critical to enhance the efficiency of freight wagons.

This work aims to improve the design of the Y25 bogie dedicated for Iberian gauge railway, considering a Lightweight Chassis Design, and exploring an increase of payload up to 25-tonne/axle. To achieve this, different chassis frame configurations are evaluated using Finite Element Analysis (FEA) to identify stress concentration points and enhance structural integrity. FEA assesses both static and fatigue loads, ensuring mechanical performance and durability. The analysis focuses solely on the bogie frame, excluding suspension elements. The mechanical and fatigue behaviour of bogie frame will be evaluated according EN 13749 and EN 17149 standards, which stablish load conditions, and strength and deformation assessments.

High-strength steels (HSS) are selected for the chassis frame due to their potential to reduce weight by up to 30% compared to conventional mild steels. HSS enables thinner gauge materials, reducing frame weight and improving manufacturing efficiency through smaller welds or plate bending. However, thinner gauge materials introduce additional structural deflection constraints that must be carefully managed to ensure dynamic stability and prevent resonance coupling. Therefore, FEA plays a key role in conducting structural performance, evaluating stiffness variations, deformation, and stress distribution.

The outcome of this study seeks to improve operational performance of the Y25 bogie, improving competitiveness of railway freight transport. The results contribute to more efficient, lightweight, and sustainable rail freight solutions, supporting the broader the European goals to railway transport.

Validation of Finite-Element Model of a MALE UAV Composite Wing with Experimental Static Bending Test

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With the increasing use of finite element (FE) analyses in the aerospace field to ensure structural safety, it is mandatory to have active validation practices to increase the reliability of the computational model simulations. This work presents a comparative study between experimental data obtained from a static bending test of a 12-meter span UAV composite wing with numerical simulations from an high-fidelity FE model using a commercially available FE analysis software. The wing failure indices and displacement contours were extracted from the simulations and compared against the measured deformation of the wing in the experimental test for five load cases. Several differences were found, including the wing failure for the last load condition, which highlights not only the importance of continuous validation procedures of the computational model but also the necessity to use safety factors during the different structural design stages. In particular, a simulation-only approach should be avoided and adequate safety factors used when sizing critical aircraft components such as the wing. Some suggestions are emphasized to further improve upon the presented FE model, including the use of non-linear analyses, adequate mechanical characterization of the materials used, closer-to-reality geometry taking into account manufacturing, and improved load and displacement boundary conditions application. Ultimately, this work provides guidelines on how to improve the reliability of FE analysis and highlights the differences that can be found between simulations and reality.

Composite Bayesian Optimisation for the Analysis and Design of Materials and Structures

Rui Coelho[1]; Francisco Pires[1]

[1]FEUP

The growing demands of modern industries require the rapid development of materials with enhanced mechanical properties, under increasingly tight technological and time constraints. Simulation-based design, enabled by advances in high-performance computing and accurate numerical modelling, has emerged as a cost-effective and flexible alternative to experimental testing. These approaches not only reduce costs but also accelerate development and can be fully automated for unsupervised execution. Achieving reliable results in this context depends on efficient optimisation strategies.

In this work, we present a composite Bayesian optimisation framework [1, 2] for the analysis and design of materials and structures. By exploiting the compositional nature of the objective function, our method drastically reduces the number of required simulations or experiments, achieving superior performance compared to state-of-the-art optimisers. Its probabilistic foundation further enables the treatment of uncertainty, making it particularly effective for stochastic objective functions with noisy observations. The framework has been successfully applied to a range of problems, including constitutive parameter identification in a crystallographic-slip model, the optimisation of beam cross-sections, and the design of polycrystalline microstructures. We also introduce piglot [3], an open-source Python package for derivative-free, unsupervised optimisation that implements these algorithms. Together, the framework and the software demonstrate a powerful pathway toward accelerating the discovery and design of advanced materials with superior properties.

[1] Cardoso Coelho, R. P., Carvalho Alves, A. F., Andrade Pires, F. M. (2024). Efficient constitutive parameter identification through optimisation-based techniques: A Comparative analysis and novel composite Bayesian optimisation strategy. Computer Methods in Applied Mechanics and Engineering, 427, 117039. https://doi.org/10.1016/j.cma.2024.117039

[2] Cardoso Coelho, R. P., Carvalho Alves, A. F., Nogueira Pires, T. M., Andrade Pires, F. M. (2025). A composite Bayesian optimisation framework for material and structural design. Computer Methods in Applied Mechanics and Engineering, 434, 117516. https://doi.org/10.1016/j.cma.2024.117516

[3] Cardoso Coelho, R. P., Carvalho Alves, A. F., Nogueira Pires, T. M., Andrade Pires, F. M. (2024). piglot: An Open-source Package for Derivative-free Optimisation of Numerical

Responses. Journal of Open Source Software, 9(99), 6652. https://doi.org/10.21105/joss.06652

MMP I: Materials and Manufacturing Processes

Complex Concentrated Alloys as a Pathway to Next-Generation Lead-Free Brasses

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Growing health and environmental restrictions on lead (Pb) have intensified the search for sustainable lead-free brass alternatives. However, despite extensive efforts involving heat treatments, machining optimisation, and finer composition tuning, replicating Pb's role in machining operations has remained a critical challenge. To address this gap, the present study explores the concept of Complex Concentrated Alloys (CCAs) as a novel pathway to design cost-effective and high-performance Pb-free brass solutions. This study represents the preliminary phase of the 'recyBRASS' project - COMPETE2030-FEDER-00576900 - a collaboration between ASBW Barbosa World Brass, S.A. and the Faculty of Engineering of the University of Porto.

CALculation of PHAse Diagrams (CALPHAD) method was employed for high-throughput screening to accelerate composition selection. An initial quaternary compositional space based on Cu(55-65)Zn(bal.)A(0-20)B(0-20), A, B $\in$ {Al, Ni, Fe, Mn, Sn} [wt%] was evaluated, resulting in more than 13,000 candidate alloys. Following this assessment, smaller additions were carried out to the selected quaternary alloys. From this set, two promising compositions were refined and selected: Cu60Al5Ni10Sn2Zn, targeting plumbing applications with a corrosion-resistant FCC-dominant microstructure; and Cu60Al1Mn5Sn5Zn, designed for automotive uses, combining balanced FCC/BCC phases and intermetallics to enhance machinability and overall mechanical performance.

The alloys were produced by casting and validated through scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS), electron backscatter diffraction (EBSD), X-ray diffraction (XRD) characterisation and microhardness tests at room temperature. Preliminary results confirmed the predictive accuracy of CALPHAD and demonstrated that the selected CCAs exhibit suitable microstructure and mechanical properties for Pb-free brass applications. Further mechanical and machining characterisation will advance their industrial application. This work provides the first evidence that CALPHAD-guided CCAs can accelerate the development of viable Pb-free brass alloys, offering a promising route toward sustainable solutions for the plumbing and automotive industries.

Development of a unified specimen for direct generation of cohesive zone law data of adhesives

Daniel S. Correia[1]; Eduardo Marques[2]; Ricardo Carbas[1]; Lucas F.M. da Silva[2]

[1]INEGI; [2]FEUP

These days, many major industrial players feel that faster mechanical characterisation procedures are required due to the rapidly expanding use of adhesive bonding in industrial applications. The currently existing methods are exceedingly time-consuming, costly, and sophisticated, removing them as an option for many industries. Given this, the development of a more agile unified method, which can significantly reduce development times and costs, has the potential to be a disruptive technology for a variety of users, including adhesive manufacturers and the electronic, automotive, and aerospace industries, among many others.

The present work displays the development of this fully integrated adhesive characterization tool [1] that can load specimens in several different conditions during a single continuous test. To this extent a novel 4-in-1 specimen, mould and its respective test apparatus, were designed considering a modified Butt Joint (mBJ) and a modified Thick Adherend Shear Test (mTAST), for the tensile and shear loading; as well as a modified Double Cantilever Beam – mDCB – [2, 3] and an Inverse End-Loaded Split – I-ELS – [3] tests for the mode I and II fracture components, respectively.

This unified specimen was studied recurring to two different adhesives, to validate it on a wider spectrum. The results from the numerical and experimental tests were then compared against the standardised methods to access their validity and the specimen's capability to properly characterise an adhesive.

[1] A.R.A.C. Faria et al., Univ. Porto—J. Mech. Solids, 1, 25–30 (2022)

[2] D.S. Correia et al., Materials, 16, 2951 (2023).

[3] D.S. Correia et al., Materials, 17, 1049 (2024).

Valorisation of Al-Si Secondary Alloys through Controlled Rare Earth Microalloying

Helder Nunes[1 2]; Manuel F. Vieira[1]; Ana Reis[1]; Omid Emadinia[2]
[1]FEUP; [2]INEGI

The automotive and manufacturing industries are undergoing a profound transformation as they strive to reduce carbon emissions, improve fuel efficiency, and extend the service life of components. Aluminium secondary casting alloys, particularly Al-Si based systems, play a central role in this transition due to their low density, corrosion resistance, and excellent castability. However, the widespread use of recycled feedstocks introduces high levels of impurities, especially iron, which promotes the formation of brittle Fe-rich intermetallic phases. These phases, such as β-AlFeSi, severely compromise ductility and toughness, presenting a major barrier to achieving the mechanical performance required in next-generation applications. These alloys are conventionally produced via recycling routes, causing limitations in their performance, thus, new approaches are needed that are both cost-effective and compatible with existing foundry practices.

Rare earth element (REE) microalloying has emerged as a promising solution. By introducing controlled additions of less than 1 wt.% of REEs such as La, Ce, it is reported to refine α-Al grains, modify eutectic Si morphology, and influence the nucleation and growth of Fe-rich phases. These effects collectively improve alloy fluidity and casting reliability, while mitigating the detrimental impact of Fe-rich intermetallics. Importantly, the low addition contents make this approach scalable and economically viable for industrial production without significant changes to process routes.

In this study, AlSi7Mg0.3 was microalloyed with La, Ce, and Mischmetal at 0.05 wt.%. Microstructural characterisation using optical and scanning electron microscopy, supported by image analysis, was employed to examine the influence of those REEs on grain structure and Fe-rich phase morphology. Mechanical testing provided further insight into the relationship between microstructural modification and alloy performance.

Debonding methods for electric vehicles battery packs

Vasco Rodrigues[1]; Eduardo Marques[2]; Ricardo Carbas[1]; Lucas da Silva[2]
[1]INEGI; [2]FEUP

The rise of electric vehicles (EVs) with lithium-ion batteries supports net-zero goals, but growing production will further lead to more battery waste. The current use of permanent joining techniques complicates disassembly, limiting serviceability, recycling and reuse. With no design-for-disassembly mandate for OEMs, this work explores experimental debonding methods of two adhesive bonded parts of the EV battery pack, being the lid sealants and pressure sensitive adhesives (PSAs) used as cushioning between prismatic cells. A novel heat trigger primer is analysed to serve as a debondable interface layer between the adhesive layer and the substrate. The primer is triggered at 150ºC for a few seconds, weakening the adhesion to the adhesive and enabling debonding at room temperature. Although its adhesion to epoxy and polyurethane systems is relatively high, it revealed weaker adhesion when bonded to saline-based adhesives, limiting its effectiveness as a primer. For the PSAs between prismatic cells, a novel stretch & release tape was studied. Results show improved strength of the tape when benchmarked with commercial PSAs with the advantage of low force stretching and debonding. Additionally, the required stretching force is estimated to be up to 30 times lower than that needed to separate prismatic cells bonded with conventional PSA solutions, indicating significantly easier cell separation.

Atomic-Scale Visualization of Moiré Patterns in Graphene Using TEM

Luis Eduardo Piedra Marin

International Iberian Nanotechnology Laboratory

Twistronics is an emerging area of research focused on how rotating layers of 2D materials relative to each other affects their electronic behavior. By controlling the twist angle, researchers can engineer quantum materials with tailored properties. The formation of Moiré superlattices strongly influence the local electrostatic potential, charge distribution, and electric fields in 2D materials. Analyzing these Moiré patterns is essential for understanding their underlying properties. In this study, we used a JEOL JEM-2100 transmission electron microscope operating at 200 kV, to achieve atomic resolution of Moiré patterns in graphene. Twist angles were quantitatively extracted through fast Fourier transform (FFT) analysis of the TEM images, by identifying the relative orientation of diffraction spots corresponding to each atomic lattice. This method enables precise determination of interlayer rotation and provides critical insight into the resulting Moiré superlattice geometry. Multislice computer simulations were employed to complement the experimental observations by generating 4D-STEM images, enabling the calculation of the projected electric field (eCOM), charge distribution (dCOM), and electrostatic potential (iCOM). The integration of TEM imaging and advanced computational modeling provides a detailed framework for investigating the electrostatic properties of twisted layers of 2D materials.

Hydrogen environmental embrittlement in high-strength steels and their welds: from unified continuum-mechanics modeling to insitu experimental characterization

Duarte Cachulo
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Hydrogen embrittlement remains one of the most critical challenges to the safe and reliable application of metallic materials in hydrogen-based energy systems. Its complexity arises from the interplay of multiple microscopic mechanisms, such as hydrogen-enhanced localized plasticity (HELP), adsorption-induced dislocation emission (AIDE), hydrogen-enhanced strain-induced vacancy formation (HESIV), and hydrogen-enhanced decohesion (HEDE), which act in competition to determine fracture behavior. This work is in its early stages of development and proposes a comprehensive numerical–experimental framework capable of predicting failure in metallic structures exposed to pressurized hydrogen environments, while also providing fundamental insight into the underlying fracture processes.
The numerical framework is built on the implementation of a constitutive model coupled with a hydrogen diffusion model, designed to represent fracture as the result of competition between plasticity-driven and decohesion-driven hydrogen embrittlement mechanisms. Through a continuum mechanics approach, the model integrates hydrogen transport, stress and internal variables, along with crack initiation and propagation. The experimental campaign involves the development of a novel in-situ fracture toughness testing setup in pressurized hydrogen environments, which will be validated and refined in close synergy with the numerical model.
Once validated, the numerical and experimental tools will be used to clarify the influence of operational conditions and material properties, including microstructural features and phase distributions, on the dominant HE mechanisms. Particular attention will be given to high-strength steels, specifically grades 4130, 4140, and API 5L X80, and their welds, which will serve as the primary material systems under investigation. Fractographic analysis will complement numerical predictions to identify failure regimes and establish correlations between experimental observations and simulated fracture processes. Ultimately, this ongoing work aims to advance the scientific understanding of hydrogen embrittlement while also developing predictive tools and testing strategies that can be transferred to industrial applications in the emerging hydrogen economy.

BIO I: Biomechanics

Application of statistical shape models in the 3D reconstruction of the scapula and estimation of the glenohumeral joint center from limited data

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In shoulder modeling, particularly in motion analysis, estimating the glenohumeral joint rotation center (GH-r) is an essential component. However, existing predictive models for estimating the GH-r often exhibit limited accuracy. Recently, methods based on statistical shape modeling—a technique commonly used to generate subject-specific bone morphologies—have demonstrated superior performance compared to conventional predictive approaches in estimating joint centers. The aim of this study was to propose and evaluate two reconstruction methods based on statistical shape models (SSMs) capable of simultaneously performing 3D reconstruction of right scapulae and estimation of the GH-r from a limited set of palpable landmarks, typically measured with motion capture systems. An SSM of the scapula, augmented with the GH-r, was built from 44 geometries segmented from computed tomography (CT) scans. The GH-r was computed through spherical fitting of the humeral head. For the reconstruction of bone geometry and GH-r, two SSM-based algorithms were developed using four palpable scapular landmarks and anthropometric variables as input: one predicted the SSM weights through optimization (SSM-Opt), and the other predicted the weights through linear regression (SSM-LR). For comparison, a predictive method using linear regression (Sobral-LR) was also implemented using the same training dataset as the SSM. All methods were evaluated on a test set composed of 15 scapula geometries, with the GH-r obtained by spherical fitting serving as ground-truth. Both SSM-based methods showed improved GH-r estimation compared with existing approaches and produced scapular reconstructions consistent with results reported in the literature. The SSM-LR, SSM-Opt, and Sobral-LR methods achieved mean Euclidean distance errors of 3.77 mm, 5.02 mm, and 6.38 mm, respectively, in GH-r estimation. The differences between the SSM-LR method and the other two were statistically significant. These results support the use of SSMs to improve GH-r estimation and enable personalized scapula reconstruction from limited data.

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FEDER-00703600), supported by national funds from FCT and European funds by FEDER. The authors express gratitude to the Free Access Decedent Database, funded by the National Institute of Justice, United States (grant number 2016-DN-BX-0144), for providing the whole human body computed tomography (CT) scans that were instrumental in enabling this study.

A Geometry Based Simplified L4-S1 Finite Element Model for Topology Optimization of Spinal Cages

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Back pain has been the leading cause of disability globally since 1990. It is estimated that by 2050, back pain will affect approximately 800 million people. Among the various conditions contributing to back pain, intervertebral disc degeneration is a significant factor, often leading to segmental instability and the need for surgical intervention. In such cases, interbody cages are often used to restore mechanical stability and to promote spinal fusion.

This study focuses on interbody cages specifically designed for the lumbosacral region, particularly at the L5-S1 level, critical for upper body support and associated with severe clinical disorders. The anatomical characteristics of this level remain insufficiently addressed by market solutions, emphasizing the necessity for more optimized cage development strategies. To address this, a simplified geometric finite element model of the L4-S1 segment was developed in ABAQUS to support cage design through topology optimization. The model was constructed based on anatomical measurements and commonly reported material properties. The aim is to evaluate the feasibility of using a model based only on dimensional, material, and angular constraints as an alternative to complex medical imaging-based models generally found in the literature.

The model was verified by comparing average Maximum Principal Stress (Abs) values and qualitative stress distribution with those of a reference model. Topology optimization was then applied to guide the development of optimized cage designs. Optimization tasks were defined for individual and combined motions, including flexion, extension, and lateral bending to assess movement direction impact on material distribution. Design responses were based on strain energy and volume variables, as commonly used in similar studies. As a result, three cage designs were generated in SOLIDWORKS, incorporating spatially varying material properties to address local structural requirements.

By proposing a computationally efficient strategy, this study supports future research on interbody cage development through iterative design refinement and multiscale optimization, incorporating porosity based on density distributions rather than uniform structures. This approach may ultimately contribute to improving patient outcomes in spinal fusion procedures and advancing the field of spinal biomechanics.

Impact of Anterolateral Ligament Reconstruction on Knee Joint Pressure Following ACL Surgery

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Background: Residual anterolateral rotational laxity after anterior cruciate ligament reconstruction (ACL-R) has driven increasing interest in complementary extra-articular procedures such as anterolateral ligament reconstruction (ALL-R). However, concerns remain regarding their potential impact on lateral tibiofemoral compartment pressure, a factor associated with osteoarthritis progression.

Objective: To evaluate whether combining ALL-R with ACL-R influences lateral tibiofemoral compartment pressure compared with isolated ACL-R.

Methods: Forty-seven patients (mean age 29.1±11.3 years; 72.3% male) who underwent ACL-R between 2020 and 2023 were included: 19 with isolated ACL-R and 28 with ACL-R+ALL-R. One year postoperatively, functional outcomes (KOOS, IKDC) and gait analysis (Xsens inertial system) were assessed. Compartment pressures during walking, running, and stair-climbing were estimated using musculoskeletal modeling software (Anybody).

Results: No significant differences in lateral tibiofemoral compartment pressure were observed between groups (mean difference 0.040 MPa, p=0.620). Functional outcomes were comparable, with no significant differences in KOOS (p=0.825) and IKDC (p=0.962) scores.

Conclusion: The addition of ALL-R to ACL-R does not significantly affect lateral tibiofemoral compartment pressure at medium-term follow-up, suggesting it does not over-constrain the knee. These findings indicate that ALL-R is unlikely to increase osteoarthritic risk through compartmental pressure changes.

A rotational driving constraint based on relative Euler parameters for redundancy-free multibody kinematics and dynamics

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Multibody systems are a valuable tool to study the biomechanics of the human body. In biomechanics, the standard methodology is to perform a kinematic analysis followed by an inverse dynamic analysis. Motion data acquired in laboratory of motion usually serves as prescribed data. The kinematic constraints include the driving constraints used to guide degrees of freedom (DoFs) of the system. The formulation of rotational driving constraints equations using angles (angle-based formulation) introduces numerical instabilities and dependency among the kinematic constraints. The redundancy may be dealt with by restricting the range of motion evaluated (to avoid joint angles close to 0º or 180º) or by adding a driving constraint that guides the same degree of freedom (DoF). The presence of redundancy may lead to an over-constrained system and specialized methodologies are required. Since the Euler parameters avoid singularities, they propose a good alternative to the use of angles. This work proposes an alternative formulation of rotational driving constraint based on the relative Euler parameters (Euler-based formulation). In this formulation, the relative rotation around a relative axis of rotation, between a kinematic pair, is guided. The number of required rotational driving constraint equations is equal to the number of degrees of freedom to be guided, resulting in independent kinematic constraints. Kinematic and inverse dynamic analyses were conducted using an in-house multibody model of the human body, and comparisons with literature were performed when available. The 3D multibody model consists of 26 rigid bodies constrained by 27 kinematic joints. These joints belong to open kinematic chains (e.g., legs and arms) or to closed kinematic chains (shoulder girdle). Kinematic data was collected from the database of the Lisbon Biomechanics Laboratory (LBL) and included motions of the upper and lower limbs: abduction in the frontal plane, forward flexion in the sagittal plane, reaching behind the back, combing the hair and right gait cycle. A population of 8 test subjects was used for the upper limb motion (4F, 4M; mean weight, 70.29±14 kg; mean height, 1.72±0.12 m), and a single test subject for the gait cycle (due to the lower inter-subject variability). Kinematic and inverse dynamic analysis were conducted to compute joint angles and joint torques. The results from upper limb joint angles showed good correlation between angle- and

Euler-based formulation, with differences being neglectable, considering the range of motion evaluated. The same was observed for the lower limb, as well as good correlation with literature data, with differences arising from the motion itself and not the formulation. Additionally, the use of relative Euler parameters was computationally more efficient as it produced equations and matrices simpler and more compact, which is extremely helpful in complex multibody simulations.

Polynomial Surrogates for F-Actin Networks with Compliant Crosslinkers

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Filamentous actin (F-actin) plays a central role in cell elasticity and structural integrity, forming dynamic, crosslinked networks in the actin cortex. Established mechanical models for F-actin and crosslinked filament networks successfully describe filament- and network-level behavior, but are often limited in accounting for biological dynamic processes and inherent material uncertainty and variability.
We develop a stochastic modeling framework that integrates Polynomial Chaos Expansion (PCE) surrogates using the Finite Element Method (FEM). These surrogates replace filament-scale mechanical models for F-actin networks with compliant linkers, efficiently enabling uncertainty quantification and sensitivity analysis of key material parameters. First- and second-order statistical moments from the PCE surrogates are incorporated into a micro-sphere network model and implemented via a user-defined material subroutine in general purpose finite element program Abaqus, avoiding modifications to the equilibrium equations.
Validation against Monte Carlo simulations, performed for single cubic elements of unit length under simple deformation modes and for a rheology setting, demonstrates that our approach accurately captures the network-scale mechanical response together with its statistical variability, while reducing computational cost.
This methodology offers a scalable route for incorporating intrinsic material variability into F-actin mechanics simulations, with implications for studying cell motility, division, and pathologies related to cytoskeletal remodeling.

H-Move: A Novel Multibody Tool Based on Fully Cartesian Coordinates and a Generic Rigid Body Formulation for Biomechanical System Analysis

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Multibody system dynamics provides an efficient framework for modeling biomechanical systems. Various multibody formulations have been proposed, differing in how they represent rigid bodies, the type of coordinates employed, and the complexity of the associated constraint and state equations. Recently, the authors of this study introduced a novel global multibody formulation, titled Fully Cartesian Coordinates with a Generic Rigid Body (FCC-GRB), and validated it using a series of classical benchmark problems. Due to the nature of the coordinates used and its modeling strategy, this formulation is particularly well suited for biomechanical applications. However, its validation within the context of biomechanics remains limited.
Hence, this study aims to validate *H-Move*, a generic multibody tool based on the FCC-GRB formulation, for the analysis of biomechanical systems. To this end, a comprehensive modeling workflow is presented for the representation of skeletal and musculoskeletal systems, including contact dynamics. The study also introduces a mixed coordinate approach for inverse kinematic analysis, driven by experimental data collected using conventional marker-based MOCAP systems. To assess its practical applicability, *H-Move* software is tested on a range of biomechanical models. Finally, its use in the development of assistive movement devices is illustrated through a case study involving the modeling and validation of an ankle–foot orthosis (AFO) designed for a child with right-leg neuropathy resulting from a congenital clubfoot disorder and associated vascular malformation.
Overall, the *H-Move* software allows for the straightforward modeling and analysis of biomechanical systems with varying levels of complexity. It enables the determination of the main kinematic and dynamic outcomes typically assessed in motion analysis and includes a set of built-in routines for quantifying movement and calculating commonly used scores. Furthermore, by incorporating a mixed coordinate method, the formulation supports the simultaneous and consistent estimation of body segment positions and joint angular trajectories directly from experimental data, thereby reducing errors commonly introduced by soft tissue artifacts.

The application of *H-Move* proved instrumental not only in analyzing pathological gait but also in supporting the design of movement assistive devices. In particular, it facilitated the definition of functional requirements for an AFO and validated its expected performance, highlighting the method's relevance for developing customized therapeutic solutions.

In summary, the FCC-GRB formulation and *H-Move* software demonstrate strong potential for both conventional biomechanical modeling and clinical applications. Their ease of integration with experimental data, support for muscle and contact modeling, and ability to guide personalized assistive device design underscore their value for the biomechanics research and healthcare communities.

MMP II: Materials and Manufacturing Processes

Improving Local Formability in Sheet Injection Using Tailored Laser Heat Treatment

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The integration of functional features into lightweight aluminium components remains a key challenge in advanced manufacturing, particularly when forming operations impose severe local deformation. This study focuses on the sheet injection process, a variant of Sheet-Bulk Forming (SBF), where thickening and lateral extrusion occur in previously bent aluminium sheets [1]. The material investigated is AW6082-T6, a medium-strength Al-Mg-Si alloy widely used in transportation and structural applications due to its good strength-to-weight ratio and corrosion resistance.

To overcome formability limitations and reduce the risk of defects such as fracture and folding, a strategy based on Tailored Heat-Treated Blanks (THTB) was employed. Localised Laser Heat Treatment (LHT) was applied to selectively reduce strength and enhance ductility in critical deformation zones [2]. Mechanical characterisation was performed via tensile and compression tests on both as-received and heat-treated materials, supported by hardness mapping and digital image correlation (DIC) to assess local strain behaviour.

Experiments were conducted on a flexible SBF demonstrator using a two-stage process: bending followed by sheet injection [1]. Numerical simulations using the i-form software were performed to guide LHT pattern design and predict material flow. Among the tested strategies, one demonstrated superior performance, enabling higher injection volumes and reducing process forces while avoiding failure. The results confirm that LHT is an effective method for extending the process window of sheet injection in AW6082-T6, offering a promising solution for the production of complex aluminium components with enhanced functionality.

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Predicting the fatigue life of 18Ni300 Maraging steel produced via directed energy deposition: an heuristic method

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Additive manufacturing (AM) technologies have steadily progressed in the last decade, establishing themselves as technologies capable of producing near-net shapes with a degree of complexity that would make them unfeasible to manufacture via more conventional processes. Within these technologies, directed energy deposition (DED) has gained promince for its capacity of repairing existing components, as well as producing functionally graded materials.

However, due to the limitations of powder delivery, out-of-equilibrium cooling, concerns regarding productivity, and/or poor feedstock, process-inherent defects such as gaseous pores and oxides are generally unavoidable even under optimal processing parameters. These defects, while not necessarily critical under static loading, may be critical when considering the service life of an AM'ed part, as they reduce the crack initiation stage and act as stress raisers.

The literature suggests the use of computerised tomography (CT) to acquire the location and size of existing defects, detect the killing defect based on certain criteria, and apply a crack growth model that returns the component's service life. While this approach is valuable, its application is dependent on the size of the sample, as well as access to CT scanning equipment. Thus, this work explores the capacity of using optical microscopy imaging in order to parametrise statistical distributions of both defect size and location, and by subsequently applying an analogous stress field to the sample in question, allows the identification of the killing defect from which a macro-crack initiates.

In this work, DED'ed 18Ni300 Maraging steel specimens of bending and axial high-cycle fatigue were tested, and the obtained data served as the experimental validation for the heuristic model. Furthermore, the crack propagation behaviour of DED'ed 18Ni300 was gathered via fatigue crack propagation tests in compact tension specimens. The depositions from which fatigue specimens were obtained were analysed at multiple cross-sections, and the observed data on the defect size and location served as the basis for statistical characterisation of virtual specimens. The SN curves for the experimental tests and from the proposed method are compared.

Towards thin-walled construction by arc-based directed energy deposition via adaptive three-axis deposition strategies

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Thin-walled structures produced using Directed Energy Deposition (DED-arc) offer a high strength-to-weight ratio, enabling for the fabrication of stronger, more efficient, and sustainable components. Despite these advantages, some limitations arise, frequently related to geometric deviations and material defects, which may lead to inconsistencies in the final product.

This work delves into the manufacturing of complex thin-walled parts via DED-arc using adaptive path planning strategies considering different geometric features. This allows for eliminating the need for excessive material deposition to rectify height variations, minimizing the need for further machining operations. Deposition parameters are established by combining open-source slicing software with 3-axis CNC motion systems.

Geometrical challenges such as corners, intersections, and 55º overhangs relative to the baseplate are successfully tackled during the pre-processing stage of DED-arc. The methodologies are validated with the construction of a pillar-beam connection prototype in ER70-S low-carbon steel, by combining the different path optimization strategies that lead to automatic process parameter adjustment. Dimensional accuracy, quality and mechanical integrity of the as-built parts remain uncompromised, confirming this works suitability for steel construction.

Characterization of Green Feedstock for Additive Manufacturing – Case study of a High-strength Aluminium alloy powder

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Additive manufacturing (AM) of metals is poised to transform the manufacturing landscape. However, the metal powders used as feedstock in AM are not only expensive but also limited in variety when compared to conventional wrought alloys. This highlights the need to explore alternative methods for producing metal powders, particularly more cost-effective and sustainable options.

Metal powders for AM are characterized by their particle size, shape, particle size distribution, and structure. These powder characteristics define the metal powder properties that directly influence their performance in AM processes. Among the powder properties, spreadability is an important property for powder bed-based additive manufacturing techniques such as Laser Powder Bed Fusion (LPBF). Spreadability refers to a powder's ability to form a uniform, continuous, and uninterrupted layer during the recoating process. It reflects how well the powder can flow, level, and compact under the action of the recoater blade.

In addition to spreadability, other powder properties such as tap/apparent density and flowability play important roles in determining the suitability of a powder for LPBF. Typically, metal powders used in LPBF are produced by gas atomization, resulting in nearly spherical particles. This morphology supports good flow and spread behavior, although minor satellite particles can affect uniformity. In contrast, powders produced by mechanical methods, such as ball milling, can exhibit different spreading behavior due to their irregular shapes and surface textures.

This study investigates the metal powder characteristics and the spreadability of an upcycled powder produced from machining scrap of an aerospace-grade high-strength wrought aluminum alloy using a high-energy mechanical milling process. Its spreading behavior is compared to that of a commercial gas-atomized Al-alloy powder. The study identifies key factors influencing spreadability and evaluates the suitability of mechanically milled powders as alternative feedstocks for LPBF.

Chemical-mechanical Devulcanization of SBR at Low Temperatures

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The footwear industry has a strong presence in Portugal and, like any manufacturing sector, produces waste and scraps. Styrene–butadiene rubber (SBR), a synthetic rubber, is commonly used in shoe sole production. This study explores the potential of reusing these rubber scraps by devulcanizing them through a low-temperature chemical–mechanical process and then incorporating the devulcanized material into new, virgin material.

To evaluate this, the feasibility of devulcanizing the material was tested using a two-roll mill and an internal mixer. On the two-roll mill, conditions with 2, 2.2, and 4 phr of devulcanizing agent 1, along with 20% processing oil and 3.3 phr of agent 2, were tested to assess the effect of the chemical agent. A sample without the chemical agent was also processed. The samples were devulcanized for 20 minutes, with material removed every 5 minutes for characterization and evaluation of the devulcanization level. For devulcanization in the internal mixer, several conditions were evaluated to study the effects of time, temperature, and chemical agent concentration.

Next, the samples underwent Soxhlet extraction and subsequent characterization of the devulcanized material using swelling methods. FTIR and thermogravimetric analysis further evaluated the devulcanized rubber.

The optimal conditions for each methodology were tested through revulcanization. In the initial stage, 20% of devulcanized material was mixed with virgin material, and the composites' mechanical properties were assessed, including rheology, tensile strength and elongation, tear resistance, density, hardness, and abrasion resistance. The most effective condition was devulcanization on the two-roll mill with agent 1 at 2.2 phr for 10 minutes.

Based on the results, the proportion of devulcanized material in the rubber increased from 20% to 30% and 50%. Finally, the processing oil content used with agent 1 was reduced from 20% to 10% and 5% at the laboratory scale. The feasibility of performing this devulcanization on industrial-scale rolls was also assessed.

An iterative design of experiments approach for 4D printing of PLA/EVA blends

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Throughout the past decade, 4D printing has emerged as a promising research field for the development of smart structures, promoting the design of applications in a variety of knowledge domains, such as robotics [1], structural engineering [2], tissue engineering [3], and pharmacology [4]. However, the stimuli-responsive behavior of additively manufactured parts has demonstrated to be strongly dependent on material formulation, specimen dimensions, programming strategy, and process parameters [5], which makes it challenging for researchers to determine the optimal conditions specific to each scenario. This study follows a structured approach based on design of experiments (DOE) to obtain the combination of printing parameters that maximize the shape recovery after thermal stimulus. A custom-made blend composed of polylactic acid (PLA) and poly(ethylene-co-vinyl acetate) (EVA) was used alongside a low-cost 3D printer based on the fused filament fabrication technique. Three DOE iterations were conducted, focusing on screening, robustness, and refinement, each of which adopting different methods, factors and levels. Across all experiments, the recovery ratio ranged from 15,39% to 92,82%, which highlights the importance of systematically investigating the process-property relationships in this scenario. Even though the results obtained cannot be extrapolated to other materials or conditions, the procedure can be adapted to analogous works in 4D printing.

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EES I: Energy, Environment and Sustainability

A Comparative Study on Indoor Air Quality, Air Stuffiness, and Air Change Rate in Classrooms with Different Ventilation Strategies

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To improve indoor air quality (IAQ) in school buildings (SBs) across the EU, an experimental survey of two classrooms at the University of Coimbra was conducted as part of the 3SqAir project. The 3SqAir project aimed to develop a common strategy for achieving sustainable solutions that ensure acceptable indoor air quality (IAQ) in classrooms. The project was conducted in Spain, Portugal, and France across six pilot demo sites. This paper focuses on the outcomes at the Department of Mechanical Engineering, Polo II Campus, University of Coimbra, Demo Site 6. The comparative evaluation of indoor air quality (IAQ), air stuffiness (AS), and air change rate (ACH) conditions in one naturally ventilated classroom and one mechanically ventilated classroom is presented for the period from September 2022 to December 2022. To characterise IAQ, the concentrations of Carbon dioxide (CO2) and particulate matter (PM2.5 and PM10) were sampled over a 10-minute time step. The ACH during occupied and unoccupied periods has been calculated using the Tracer Gas Method (TGM), using CO2 as the tracer gas. AS is obtained using one of the key performance indicators proposed during the 3SqAir project, KPIvent. The two classrooms are compared using charts and other indicators to illustrate the different air quality conditions. The results show that IAQ gaps are consistent with the ventilation system in the rooms. Corrective measures within the 3SqAir framework are suggested for approval and implementation while monitoring campaigns continue. The work presents preliminary findings on improving indoor air quality (IAQ) in schools and offers recommendations for ventilation settings to mitigate risk in extreme conditions, including considerations for energy efficiency.

Exploring the impact of indoor plants in modern offices on IEQ and workers' health, well-being and productivity

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Office workers spend a significant portion of their day at the workplace, highlighting the importance of maintaining proper indoor environmental quality (IEQ) in office buildings. These buildings are mainly located in urban areas where green spaces can be insufficient. Evidence has shown that indoor plants can enhance workplace IEQ and positively impact workers. Thus, this study aimed to assess the effectiveness of introducing indoor plants in urban offices in improving IEQ and workers' well-being, health, productivity, and autonomic nervous system (ANS) activity through a randomized controlled trial. Plant species with air-cleaning potential (*Sansevieria trifasciata, Dracaenas fragrans, and Chlorophytum comosum*) were placed in 12 office spaces (intervention group) at a density of one pot per 9 m^2, and 11 office spaces served as the control group. IEQ and workers' assessments (questionnaires: self-reported outcomes, and pupillometry: ANS activity) were performed before and after a 14-day intervention implementation. Pollutant sources (e.g., cleaning products, furniture) remained unchanged between phases, while occupancy and ventilation were recorded on assessment days. The findings indicate that indoor plants produce no significant changes in airborne particulate matter (PM), volatile organic compounds (VOC), and carbon dioxide levels between pre-intervention and intervention phases. However, a trend suggested low VOC and ultrafine particles concentrations (observed in 88% and 58% of intervened offices), while PM levels increased. Regarding workers, 130 participants were engaged in the study (intervention group: n=75, control group: n=55). Pre-intervention measurements showed that the intervention and control groups presented similar baseline well-being, diagnosed health issues, pupil parameters, productivity, and scores for office IEQ satisfaction. Findings from the comparison of intervention phase data with the baseline assessments showed that higher odds of well-being improvement were obtained in offices where VOC concentration decreased from the introduction of indoor plants. This VOC concentration reduction significantly explained 20.6% of the observed well-being improvements among office workers. Notably, the intervention group showed enhanced parasympathetic activity between study phases, as evidenced by a significant average 0.3 mm decrease in pupil diameter and increased constriction

amplitude (30.8% to 32.1%). Although no effect was detected in productivity, the level of satisfaction with IEQ was significantly higher for participants of the intervention group than for controls (averages: 3.4 vs. 3.1). Overall, the findings of this work support that the use of plants with known air-cleaning properties represents a relevant opportunity to improve office workers' satisfaction with office IEQ and parasympathetic activity, fostering a more relaxed physiological state at work.

Indoor Environmental Quality in healthcare settings: Impact of continuous monitoring system on Infection risk, Thermal comfort and Energy Efficiency

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Healthcare associated infections (HAIs) remain a major challenge in clinical environments, where airborne transmission plays a significant role in patient morbidity and mortality. Current air quality management systems in healthcare facilities often rely on periodic monitoring or static control measures, limiting their effectiveness in mitigating infection risks. This study explores the potential of continuous monitoring of airborne pathogens as an integrated solution for improving infection control, energy efficiency, and patient comfort. By deploying IoT-enabled sensor networks and advanced bioaerosol detection technologies, healthcare facilities can detect real-time fluctuations in airborne pathogen concentrations, enabling timely interventions and more precise ventilation strategies. Beyond reducing the risk of HAIs, continuous monitoring provides actionable data for optimizing HVAC operation, ensuring that airflow rates and filtration levels are adjusted in response to actual contamination levels rather than conservative setpoints. This dynamic control approach reduces energy demand while maintaining compliance with stringent healthcare standards. Furthermore, such adaptive systems can balance infection control with patient thermal comfort, minimizing over-ventilation and preventing drafts or temperature fluctuations that negatively affect recovery. Machine learning driven analytics and predictive modeling strengthen this framework by identifying patterns in airborne pathogen behavior and informing proactive facility management. The integration of continuous monitoring into healthcare infrastructure represents a pivotal step toward safer, more sustainable, and patient-centered clinical environments.

NOTE: Data measurement devices have already been placed in a university hospital in Coimbra under the scope of HumanIC project. The project has received funding from the European Union's Horizon Europe research and innovation program under the Marie Sklodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726).

Modelling for net zero and positive energy districts: integrating new technological solutions

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This study proposes an optimization model embedded in a comprehensive methodology to support economic efficient design of Net Zero Energy Districts (NZEDs) and Positive Energy Districts (PEDs). The model adopts a linear programming formulation to optimize the configuration and operation of energy systems at the district level, considering buildings' energy needs and renewable energy integration. It allows the identification and sizing of technologies for space heating, space cooling, domestic hot water, and electrical appliances, alongside photovoltaic (PV) electricity generation and battery storage systems. The model accounts for costs associated with climatization and hot water (HVAC and DHW) equipment, PV, batteries, and operational energy flows, including grid import and excess PV energy injection.

Thermal energy demand profiles are supported by detailed Urban Building Energy Modeling (UBEM), based on building-level information regarding geometry, use, and construction characteristics. This approach ensures that thermal needs for heating, cooling, and hot water are defined based on realistic simulations, reflecting both architectural and operational parameters of each building. UBEM also allows to consider envelope refurbishment scenarios and use profiles variations.

The optimization model was designed to handle the energy demand profiles obtained by UBEM for multiple buildings and to choose the energy systems necessary to achieve different objectives, including net zero energy, positive energy and self-sufficient configurations. Its flexible structure supports the comparative assessment of multiple strategies and energy technology combinations, with the capacity of studying both centralized and dwelling-level solutions, accommodating diverse consumption patterns and trade-offs between grid independence and investment costs, as demonstrated in a previous case study. The modular design of the model enables the continuous integration of emerging technological solutions, supporting iterative improvement and future-readiness. Current developments include studying the incorporation of seasonal thermal energy storage (STES) technologies, aiming to enhance the capacity of districts to reach higher levels of energy self-sufficiency and reduce grid dependency. By supporting the evaluation of innovative systems within a consistent economic

framework, the model proves to be a valuable tool for guiding early-stage NZED and PED planning toward more advanced and sustainable configurations.

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Integrated Experimental–Modelling Framework for Calorific Energy Assessment in a Microwave Dual-Mode Cylindrical Cavity

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The quantification of energy consumed by materials during microwave (MW) heating remains insufficiently addressed in the literature, despite its importance for high-temperature processing and the design of MW reactors. While reliable tools exist for in situ dielectric characterization (*Catalá-Civera, 2015*) and accurate temperature measurement (*Catalá-Civera, 2019*), direct assessment of the calorific energy consumption of materials under MW heating is scarce. By combining the measured system frequency response with electromagnetic (EM) modelling of materials with measured dielectric properties, the absorbed EM power can be estimated. When coupled with precise measurements of temperature and heating rate, the multiphysics electro-thermal modelling resolves the thermal balance of the system, linking absorbed EM power to the calorific energy consumption that governs material heating.

This study aims to extend the framework of the dual-mode cylindrical microwave cavity system, the MW-DETA (*Catalá-Civera, 2015*), by combining experimental measurements with electromagnetic and thermal modelling to characterise the calorific response of unknown materials. Frequency-response measurements are performed under three configurations: (i) the empty cavity, (ii) the cavity with the sample holder, and (iii) the cavity with a reference material (Macor) with well-established electro-thermal properties. For cases (i) and (iii), measurements are extended across temperature, with wall and sample temperatures recorded using a thermocouple and a fibre-optic system (FISO UMI-8). These data enable accurate reproduction of cavity and load geometries, as well as wall and sample properties in COMSOL Multiphysics.

The methodology seeks to decouple the electromagnetic and thermal problems by identifying a measurable proxy for absorbed power, imposed as a volumetric heat source in a 2D-axisymmetric thermal model of the MW-DETA system. The model accounts for conduction, natural convection, thin air layers, and surface-to-surface radiation, enabling verification and validation against experimental temperature data. Modelling results with the reference material already demonstrate good agreement with measured frequency responses and temperatures. While the electromagnetic and thermal models have been verified, ongoing work focuses on deriving absorbed power directly from experimental values obtained with the dual-mode tool and on extending the methodology to non-reference samples.

The Afroenergy project: Empowering Mozambique for a just energy transition and improved living conditions

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Access to energy remains one of the major structural challenges in Mozambique, marked by striking disparities between urban and rural areas. Despite gradual improvements, the 2022-23 Demographic and Health Survey revealed that only 36% of households have access to electricity, with coverage as low as 15% in rural areas, compared to 77% in urban areas. This limited energy access drives widespread reliance on fossil fuels and traditional biomass – particularly firewood and charcoal – for essential needs such as cooking, lighting, and heating, thereby exposing occupants to significant environmental and health risks.

In parallel, housing conditions are often precarious, especially in rural areas and urban peripheries. Dwellings are frequently overcrowded, lack proper spatial compartmentalization – with single rooms serving multiple functions – and are constructed using rudimentary materials such as zinc sheets, grass, earth blocks, and wood. These physical conditions exacerbate thermal discomfort, promote poor ventilation, and provide minimal protection against airborne pollutants.

The combination of biomass combustion in poorly ventilated indoor environments and substandard building construction contributes to a marked degradation of indoor air quality. This is evidenced by elevated levels of particulate matter (PM2.5) and carbon monoxide, both of which are known to increase the risk of respiratory, cardiovascular, and other pollution-related diseases – especially among vulnerable groups such as children, women, and the elderly. Therefore, systematic assessment of indoor environmental quality in these settings is essential to quantify health impacts, inform public health strategies, and guide the implementation of equitable and sustainable energy transition solutions.

The AfroEnergy project was established to directly address these structural challenges by fostering the technical and scientific training of Mozambican students, researchers, and institutions in the assessment of indoor air quality and the energy performance of dwellings. Developed through a collaborative partnership between Lurio University (Mozambique) and the University of Coimbra (Portugal), the project delivers capacity-building activities, provides accessible environmental and energy monitoring equipment, and supports the establishment of a dedicated university laboratory for energy and sustainability research. These initiatives aim to strengthen institutional autonomy to investigate and intervene in vulnerable housing contexts, foster community engagement, and ensure the continued application and replication of effective, context-appropriate solutions. Ultimately, the AfroEnergy project contributes to embedding a culture of just energy transition in Mozambique, based on scientific evidence and tailored to the country's socioeconomic and climatic realities, and reinforces the role of academic institutions in local development.

EES II: Energy, Environment and Sustainability

Design of Nanostructured LFP-Based Cathodes via Ultra-Low CNT Loading

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The development of high-performance lithium iron phosphate (LiFePO4, LFP) cathodes requires careful optimization of both electronic conductivity and electrode composition to address LFP's inherently low electronic and ionic transport properties. Traditional approaches rely on high loadings of conductive carbon black (CB), which often sacrifice energy density and mechanical cohesion. In this study, it is presented a two-stage electrode design strategy that enables efficient charge transport using an ultra-low content of multiwalled carbon nanotubes (MWCNTs) and a finely tuned LFP:PVDF ratio. The goal was to assess whether a minimal amount of MWCNTs (0.043 wt.%) could replace conventional CB and to determine the compositional window where ionic and electronic conductivity remain effective.

In the first part of the study, we compared a conventional cathode formulation (80 wt.% LFP, 10 wt.% PVDF, 10 wt.% CB) with a nanostructured cathode modified with 0.043 wt.% MWCNTs (80 wt.% LFP, 19.957 wt.% PVDF). The CNT-containing electrode exhibited comparable electrochemical performance. Additionally, the MWCNT-based electrode retained its electrical conductivity across a wide temperature range, whereas the CB-based cathode showed a temperature-dependent drop in conductivity.

In the second part of the study, it was investigated the influence of varying LFP content (from 70 to 95 wt.%) while maintaining a constant 0.043 wt.% MWCNT loading. The results revealed that sheet conductivity, while decreasing with reduced LFP content, remained within the same order of magnitude (between 103-104 S.cm-1). Electrochemical characterization indicated that the 75 wt.% LFP formulation delivered the best compromise between conductivity, capacity retention, and rate capability, retaining approximately 80% of its initial capacity across various C-rates.

Overall, this study demonstrates that ultra-low amounts of MWCNTs are sufficient to build an effective, thermally stable conductive network, allowing for flexible tuning of the active material-to-binder ratio without significant losses in electrochemical performance. The 75 wt.% LFP + 0.043 wt.% MWCNT formulation emerged as the most balanced design, combining high rate capability, structural integrity, and conductivity. These results offer a simple, scalable route for cathode engineering, with potential implications for reducing carbon content in lithium-ion batteries without sacrificing functionality.

Driving Sustainability in Solid-State Battery Design: A Regulatory Blueprint for Ecodesign Excellence

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The design and development of new battery solutions for more affordable, safe, and sustainable electric vehicles are crucial for the European Union's goal of transitioning towards a carbon-neutral economy. Solid-state batteries are the next generation of batteries and are expected to provide higher energy density, improved safety, and increased durability. These technical benefits can boost public interest in electric vehicles and reduce the overall impacts of the transport sector. The development stage of these new batteries is reaching a critical point where effective changes can still be made before finalising the design and implementing measures within its system to develop a more sustainable solid-state technology and value chain.

In this context, new European legislative documents have been created to support the sustainable development of clean technologies. The requirements and objectives outlined are expected to influence and shape the design decisions of new battery technologies, including their supply chain. This work presents an analysis of three main regulatory documents—the Battery Regulation, Ecodesign Regulation, and the Critical Raw Materials Act (CRMA)–to identify sustainability parameters applicable for the ecodesign of solid-state batteries. In analysing these regulatory documents, the Ecodesign Regulation provided a general set of ecodesign parameters for products in the European market, though only some may be applicable to battery systems. The Battery Regulation established more specific, mandatory requirements for new batteries entering the European market, mainly related to the battery's lifecycle impacts, integrated active materials, and the recycling process. Lastly, the CRMA focused on objectives for the strategic raw materials value chain, identifying parameters for sourcing and recycling.

The analysis resulted in a final set of parameters, highlighting key aspects to consider in the ecodesign of solid-state technology, encompassing the entire lifecycle and aligning with the current regulatory framework. Most parameters are linked to the initial design and manufacturing stages, directly impacting the overall environmental, economic, and social performance of the solid-state battery during use and at end-of-life. This work offers solid-state battery developers a structured

map of sustainability parameters for regulatory compliance and the promotion of sustainability. The identified parameters help bridge the gap between regulatory requirements and the practical design of emerging clean technologies, fostering a competitive and sustainable battery value chain. This research provides a vital actionable pathway for implementing measures to incorporate sustainability principles into solid-state battery design before commercialisation.

Towards Lab-Scale Implementation of a Heat Pump–Organic Rankine Cycle Carnot Battery

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The transition towards renewable-based energy systems requires large-scale and flexible electricity storage technologies to mitigate intermittency and ensure grid stability. Carnot Batteries (CB) have emerged as promising solutions, storing electricity through a reversible Heat Pump–Organic Rankine Cycle (HP–ORC) coupled with Thermal Energy Storage (TES). Unlike electrochemical batteries, CBs are site-independent, scalable, and economically attractive for long-duration applications.

This work presents a numerical framework for designing and optimizing an HP–ORC Carnot Battery, with the objective of identifying optimal nominal operating conditions to support the development of a laboratory-scale prototype. Six CB configurations were modelled, including basic and regenerative layouts as well as a two-stage heat pump. Four environmentally friendly working fluids (R1233zd(E), R1234ze(Z), R1336mzz(Z), and R1224yd(Z)) were considered in sixteen possible combinations. A two-step optimization strategy was adopted: (i) single-objective optimization, where each system and working fluid pair was evaluated separately in terms of round-trip efficiency, exergy efficiency, and levelized cost of storage (LCOS); and (ii) multi-objective optimization, applying NSGA-II and Pareto Search to identify trade-offs and derive a Pareto front between thermodynamic and economic criteria.

Results demonstrate that regenerative configurations consistently outperform basic layouts, while the two-stage heat pump shows limited benefits for low temperature lifts. The R1233zd(E)–R1233zd(E) combination provided the best overall compromise between efficiency and cost, with R1234ze(Z) in the HP cycle also yielding competitive results. The optimal design point achieves a round-trip efficiency of 81.3% and LCOS of 1.09 €/kWh, values that position CBs as highly competitive among long-duration storage technologies. Component-level analysis further highlights that heat exchangers and storage tanks account for the majority of system costs, whereas the ORC turbine is responsible for the largest share of exergy destruction.

By combining thermodynamic, exergetic, and economic perspectives (3E framework), this study provides a comprehensive tool for guiding both working fluid selection and component design. The findings directly support the construction of a small-scale HP–ORC CB test rig currently under development, while also offering insights for the future scale-up of Carnot Battery systems towards industrial and grid applications.

Anode-less solid-state batteries with a ferroelectric electrolyte: improved performance

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The development of advanced battery technologies plays a central role in the global transition toward a more sustainable and electrified society. As energy systems shift away from fossil fuels, efficient and durable energy storage is essential to support electric mobility, renewable energy integration, and decentralized power grids. Batteries are thus critical not only for enabling technological progress, but also for achieving environmental goals such as lowering greenhouse gas emissions and improving resource efficiency. To meet these objectives, next-generation solid-state batteries must combine high performance with sustainable design, prioritizing the use of abundant, non-toxic, and recyclable materials. In this context, anode-less (or anode-free) battery architectures have emerged as a promising alternative, enabling the elimination of excess lithium and the use of more environmentally friendly components.

Anode-less battery configurations are gaining growing interest from the research community due to their potential to significantly enhance energy density, reduce material consumption, simplify cell architecture, and improve sustainability by eliminating the need for pure lithium metal layers. However, despite these advantages, several critical challenges remain. Chief among them is the controlled nucleation and uniform deposition of lithium on the current collector, which directly impacts plating stability, cycling reversibility, and the overall integrity of solid-state interfaces.

At the Materials for Energy Research (MatER) laboratory, anode-less pouch cells were developed using LiFePO4 as the cathode material and a ferroelectric solid electrolyte, Li2.99Ba0.005ClO. To facilitate lithium nucleation, the surface of the negative current collector was modified with a thin ZnO coating, which effectively acted as a nucleation layer for uniform lithium deposition. The cells were hermetically sealed using pilot-line equipment to maintain a good contact between components while minimizing exposure to oxygen and moisture, thereby enhancing the cell’s longevity and performance stability. Given the fully solid-state nature of these cells, optimizing the interfaces and interfacial contact between components is critical. In this work, we present a series of targeted improvements across multiple cell elements, aimed at reducing internal resistance and enhancing performance during the discharge phase, the period in which the battery delivers energy and thus defines its practical functionality and relevance.

European Regulations for the Digital Product Passport Implementation – A Transition to a Sustainable Economy

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The EU has been actively combating climate change by promulgating regulations to preserve citizens' health and well-being and protect natural resources. The EU established several regulations supporting the transition to a more sustainable and circular economy.

The European Green Deal (EGD) adopted a set of proposals aligned with the EU's climate, energy, and transport policies to reduce the net greenhouse gas emissions by at least 55% by 2030. The Circular Economy Action Plan (CEAP) emphasises the role of production design in transitioning from linear to circular economic models. Published in 2020, CEAP proposes frameworks for decoupling economic growth from resource use and shifting to circular production and consumption systems. The Zero Pollution Action Plan creates pollution-free environments and reduces premature deaths and diseases caused by pollution, particularly affecting vulnerable populations, including children, the elderly, disabled individuals, and those in lower socio-economic conditions. The "Fit for 55" package, defined in 2021, presents proposals across climate, energy, fuels, transport, buildings, land use, forests, and taxation sectors to achieve the EU's 2030 climate targets toward neutrality. The Green Deal Industrial Plan, introduced in 2021 following Russia's invasion of Ukraine, enhances EU competitiveness and supply security while reducing dependency on essential commodities and technology imports. It positions the EU at the forefront of markets emerging from global decarbonization efforts. The Ecodesign for Sustainable Products Regulation (ESPR), effective in 2024, improves circularity, energy performance, and environmental sustainability of EU market products by establishing mandatory minimum design standards.

Digital solutions can accelerate the transformation to a more sustainable economy and the EU's competitive sustainability. Within this context, the Digital Product Passports (DPPs) are gaining attention in political agendas. According to the ESPR, introducing the DPPs will be mandatory and require that products are only sold or put into service when accompanied by a DPP. CEAP has proposed the gradual introduction of DPP in at least three sectors: textiles, construction, and electric vehicle batteries. In battery sector, digital passports are crucial for the traceability of materials in battery supply chains, as they serve as a comprehensive data repository that tracks the lifecycle of batteries, ensuring that stakeholders have access to essential information like the origins of materials and how they were produced, supporting the recycling and reuse of these critical raw materials, thus reducing waste and increasing resource efficiency. DPPs envisage supporting the transition towards a more sustainable and circular EV sector by facilitating transparency and traceability, addressing responsible resource use, and facilitating lifecycle management.

Challenges and breakthroughs towards the automation and electrification of forestry heavy machines

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Activity sectors such as forestry, agriculture, and construction are currently facing significant challenges, including a diminishing workforce and persistent hazardous working conditions. Additionally, stringent policies are pressuring companies to reduce their carbon footprints and adopt sustainable operational practices. These circumstances call for a disruptive transformation in tools and methods, emphasizing process automation and the transition from internal combustion engines (ICE) to electric-powered machinery.

This work describes the efforts conducted in the past years by our research team at ADAI concerning the automation and electrification of forestry heavy machinery. The multiple challenges in perception, navigation and robustness are described in detail, as well as the physical implementation and testing of the developed prototypes in an operational scenario. The development of the world's first fully Electric Autonomous Robotic Forestry Mulcher, from the conceptual stage to the implementation, is also presented. The tracked machine weighs 1,500 kg and is powered by two electric motors for locomotion and one dedicated to tool operation. It features a 60 kWh battery pack, providing an estimated autonomy of 2.5 hours. Designed with modularity in mind, it supports various fully electric tools. In its forestry configuration, the machine is equipped with an electric forestry mulcher for clearing ground-level vegetation.

For localization, the machine relies on GNSS-RTK systems, while its perception and navigation are enabled by a multimodal sensor fusion approach. This integrates thermal imaging, RGB-D cameras, and LiDAR sensors to detect obstacles, perceive the environment, and navigate autonomously. Communication is facilitated through 5th-generation wireless networks (5G) or a local network connected to a nearby base station. All systems operate within a Robot Operating System (ROS) environment. The software allows users to define missions or simple trajectories for the machine to follow.

The required developments and novelties in terms of design, construction, software, and electronics are thoroughly described.

Furthermore, a description of the required infrastructure and potential adoption in the actual context of forestry operations is presented, as well as a feature

comparison to similar ICE and electric machines.

The study concludes with insights into the applicability of such a machine across forestry and other activity sectors, emphasizing the trends toward automation and electrification.

SMS II: Structures and Mechanical Systems

A Unified Approach to Contact between Rough Surfaces: Contact Homogenisation with the Method of Multiscale Virtual Power

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Surface roughness permeates through all engineering surfaces and mechanical contact interfaces. Finite element analysis of nominally smooth interfaces with non-penetration and Coulomb friction models can be understood as phenomenological approximations to reality, which encapsulate the effect of roughness. However, accurate physical and mathematical representations of the real world rely on a detailed description of the physics developing at this length scale.

Injecting roughness directly into nominally smooth meshes is currently not a viable solution, due to the sheer computational cost. Contact homogenisation emerges as an alternative to embed the effect of roughness without drawing every peak and valley over the contact boundary. They leverage the simulation of two scales: the macroscale (component level) and the microscale (roughness level). These are coupled by a scale-transition theory, where the macroscale provides the displacement and strain that drive the microscale simulation, while the latter homogenises the macroscopic contact traction vector. The results of the model can be post-processed to extract relevant parameters, for instance, the coefficient of friction.

The central concepts of contact homogenisation have been around longer than two decades, but the different fronts have lacked unification and alignment with contemporary multiscale modelling frameworks. The present contribution attempts to harmonise the contact homogenisation models in the literature by employing the Method of Multiscale Virtual Power (MMVP), a methodology that fosters a systematic approach to multiscale modelling. Combining the MMVP and core ideas from the literature, two novel homogenisation approaches have been proposed, implemented and verified for different classes of contact problems [1,2]. Both alternatives adhere to three key aspects. First, they are fully general and can analyse both periodic and non-periodic contact boundaries. Second, they generate the models in the literature as particular cases. Last, they respect the physical conditions of the microscopic contact problem and the variational link between the macroscale and microscale.

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Wing Fatigue in the VHCF Regime: Numerical and Experimental Simulations

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Aerospace thin-sheet mechanical parts are often subjected to transverse loading through high-frequency vibrations. New components produced using the emergent metal additive manufacturing technologies are, therefore, expected to withstand these fatigue loading conditions up to the very high cycle regime, executing billions of cycles in their service time. The present work applies recent findings in ultrasonic fatigue testing to the development of a novel cantilevered bending ultrasonic fatigue specimen geometry in additively manufactured (AM) AlSi10Mg aluminium alloy, designed to induce failure at the built-in end. The objective lies with bridging the gap between material and component testing through the reproduction of similar fracture conditions, namely the imposition of maximum stresses at the root, thereby improving the characterization of AM materials.

Preliminary designs in PLA and Al 7075 sheet metal were created for a more time and cost-effective assessment of the proposed geometry. Numerical analysis guided the design process, ensuring excitation of the third natural bending mode at the frequency of 20 kHz and an appropriate distribution of bending stresses across all designs. Experimental testing followed using the setup present in Instituto Superior Técnico, validating the numerical results and the linear relationship between the machine power and the specimen's displacement and stress amplitudes.

FE2 Modelling of Localisation with Second-Order Homogenisation with Emphasis on the Impact of the RVE Length and the Interplay between Mesh-Dependency Across Scales

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Employing multi-scale based on computational homogenisation to model the failure of structures and components remains a challenging endeavor since strain localisation and softening lead to mesh-dependent effects across spatial scales.

This contribution investigates the attenuation of mesh-dependency in multi-scale computational-homogenisation-based models, including the role of the RVE length and the combined effects of micro- and macro-scale softening. To that end, three FE2 examples are presented, considering a macroscopic geometries promoting strain localisation and porous RVEs to mimic ductile failure mechanisms.

A brief overview of first- and second-order computational homogenisation is included, in the context of microstructures containing voids. A constitutive model for finite strain elastoplasticity is adopted, together with a simple damage evolution law. Second-order homogenisation reduces macro mesh-dependency and prevents spurious deformations due to the introduction of a macroscopic intrinsic length-scale. This length-scale is intimately related to the RVE length, which is herein interpreted mainly as a numerical parameter. Its role in the resulting second-order multi-scale predictions is carefully assessed, and the limitations of this hypothesis are analysed.

The second-order FE2 response for RVE lengths approaching zero does not converge to its first-order counterpart, as some second-order effects are preserved. Differences in RVE kinematics using first- and second-order homogenisation formulations also inhibit the convergence of the FE2 responses. Moreover, the second-order multi-scale formulation considered in this contribution does not tackle RVE mesh-dependency, which persists due to microscopic softening sources. The impact of micro-scale softening is examined by adopting a nonlocal damage model, yielding an important reduction in RVE mesh-dependency. Attenuating micro mesh-dependency increases the effectiveness of macro-scale regularisation, demonstrating the intricate interplay between mesh-dependent effects at both scales, particularly in the presence of pronounced localisation.

Effect of the temporal discretization of contact forces on dynamic contact simulations using modified mass matrix

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Dynamic contact simulations using finite element methods with Lagrange Multipliers present significant computational challenges, most notably the emergence of spurious oscillations in the multipliers—commonly referred to as *chattering*. This phenomenon arises from the reformulation of the contact problem as a Differential-Algebraic Equation (DAE) of index 3, due to the inclusion of non-penetration constraints at contact interfaces.

Recent research proposes several strategies to address this issue, among which the non-standard quadrature rules for the mass matrix, introduced by Hager and Wohlmuth [1], are particularly promising. These lead to modified mass matrices, referred to as Q_0 and Q_1, which have shown the ability to suppress chattering. In this work, we extend the Q_1 formulation to quadratic elements and evaluate its performance through numerical experiments. Notably, the Q_0 modified mass matrix does not achieve optimal convergence in contactless bending tests for quadratic elements, though this effect is less critical in contact scenarios where convergence is naturally degraded. However, the Q_1 is capable of preserving the optimal rates, and for contact examples, the proposed formulation delivers consistent behavior in good agreement with the results obtained with the original linear-element formulation.

The study also explores the influence of the contact force discretization parameter, α_c, within the Generalized-α time integration scheme. Two specific cases are considered: $\alpha_c = 0$ and $\alpha_c = \alpha_f$, where α_f controls the integration of internal forces. The results show that when $\alpha_c = \alpha_f$, simulations using the consistent mass matrix suffer from significant instabilities, while the modified mass matrices remain stable. In contrast, for $\alpha_c = 0$, the consistent mass matrix performs better, although the modified matrices may experience issues on curved contact surfaces.

In summary, the most robust configurations across all test cases are: (1) the use of modified mass matrices with $\alpha_c = \alpha_f$, and (2) the consistent mass matrix with $\alpha_c = 0$. Both combinations effectively mitigate chattering and improve stability in dynamic contact simulations. These results highlight the critical interdependence of temporal and spatial discretization parameters in dynamic implicit simulations.

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Damage Modelling of Bolt-less HYPER Joints for Composite Connections

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INEGI

In the aerospace industry, the employment of new technologies is essential to meet evolving requirements and specifications. Particularly, metal-composite interfaces have become recurrent in aerospace designs, and adequate joining techniques need to be implemented to ensure structural integrity even in the presence of these discontinuities. To improve the resistance of these interfaces, Airbus developed the HYPER joint technology, where additively-manufactured metallic pins are embedded in a composite substrate. It is, however, necessary to acquire a thorough understanding of the loading behaviour of this type of joint and develop numerical models that allow this option to be certified and seamlessly explored, accelerating the validation of new designs in an increasingly competitive sector.

This work addresses the development, calibration and validation of HYPER joint models. A high-fidelity modelling strategy is adopted: the presence of important damage precursors and the participation of composite damage in the response of HYPER joints demand an approach capable of capturing the associated phenomena. For the first time, full damage considerations are applied to the case of HYPER joints: a Continuum Damage Model predicts intralaminar damage and cohesive interfaces model interlaminar degradation. Moreover, the microstructural influence of pin embedding is considered, as well as the interaction between the pin and the composite substrate. Single- and multi-pin models are validated against experimental results. Finally, seeking additional experimental evidence, post-failure HYPER joint specimens are analysed with X-ray microscopy.

A promising agreement between the models and the experimental observations is obtained, suggesting the adequacy of the chosen modelling strategy and material models. Findings also enabled the identification of phenomena that require further experimental characterisation to support the development of future simulations.

Axial Structural Stiffness Effects on Gear Dynamic Behaviour

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Gears are essential machine elements that facilitate power and motion transmission, enabling the variation of speed, torque, and direction of motion. As such, their performance has a significant impact on the overall mechanical behaviour of machines [1]. To improve the performance of geared transmission systems, it is essential to study their dynamic behaviour. One of the key factors is the gear mesh stiffness, which is typically modelled neglecting its axial component. However, recent studies have shown that the axial component does affect the overall gear mesh stiffness [2]. This work aims at evaluating the dynamic response of a gear system with and without considering the axial structural stiffness. To carry out this analysis, the dynamic model developed by Marafona et al. [3] for a gear-shaft-bearing transmission system is used, with slight modifications to enable the computation of the dynamic response in two cases: one that neglects the axial structural stiffness and one that includes it. The dynamic response was evaluated for a random sample of 10,000 helical gears, and a maximum average relative difference of approximately 63% was found when comparing the dynamic responses of the two scenarios. Additionally, it was observed that these differences increase with increasing helix angle. Aiming to understand the origin of such differences, the case with the largest difference was examined in detail, through an analysis of the gear mesh stiffness curves and their respective spectra. Regarding the gear mesh stiffness curves, an average difference of around 17% was observed. Concerning the gear mesh stiffness spectra, it was noticed that the amplitude of the first harmonic nearly doubles when the axial structural stiffness is considered. The results presented in this work, indicate that axial structural stiffness should not be neglected when evaluating the dynamic behaviour of a gear, particularly for those with higher helix angles.

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MMP III: Materials and Manufacturing Processes

Design, Manufacturing and Testing of an Innovative Ultrasonic Fatigue Specimen Composed of Cellular Structures

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Architected cellular materials have attracted significant interest due to their unique combination of low weight and tailorable mechanical properties. However, their complex geometry and non-uniform dynamic behavior present challenges for fatigue characterization, especially in the Very High Cycle Fatigue (VHCF) regime. This work introduces a novel ultrasonic fatigue specimen specifically designed to enable VHCF testing of architected lattice structures, addressing limitations of conventional fatigue testing methods.

The specimen incorporates a rhombitruncated cuboctahedron (RTCO) lattice topology, selected for its geometric stability and favourable stress distribution under high-frequency loading. It was manufactured from AlSi10Mg aluminium alloy using metal additive manufacturing, allowing precise integration of complex cellular geometries. Finite element modal and harmonic analyses were conducted to validate the specimen's resonant behaviour at 20 kHz and to predict its dynamic response.

Following fabrication, the specimen was subjected to a comprehensive experimental campaign, including static tensile tests, conventional axial and torsional fatigue tests, and ultrasonic VHCF testing on the existing system at Instituto Superior Técnico. Real-time damage monitoring is performed using piezoelectric sensors and displacement tracking, enabling early detection of failure. This research aims to understand the fatigue behaviour of architected cellular structures and to establish a methodological framework for their experimental assessment under high-frequency cyclic loading, particularly in the gigacycle regime.

Influence of Substrate Roughness and Coating Composition on HiPIMS-Coated SiAlON Cutting Tools

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The development and application of lightweight alloys and composite materials plays a crucial role in the mobility sector’s transition toward sustainability, aligning with the European Union's goal of reducing greenhouse gas (GHG) emissions by 55% until 2030. Hence, the machining efficiency of these new hard-to-cut materials for the mobility industry becomes crucial and the development of advanced cutting tools with enhanced performance is essential to improve process efficiency and extend tool life. To achieve this, the development of new and advanced cutting tool materials, the modification of tool geometry, or the optimization of coating design can be considered. In this context, coating composition and surface roughness of the tools become key factors as both factors play a vital role in tool durability, wear resistance, and high-temperature performance of the tools.

The present study investigates the impact of substrate surface roughness and coating composition on the structural, morphological, adhesion, and wear properties of multilayered coatings deposited through High Power Impulse Magnetron Sputtering (HiPIMS). Polished and unpolished SiAlON cutting tools were coated with TiN, TiAlN, TiSiN, AlCrN, and/or ZrN multilayers, with thicknesses ranging from 1.5 to 2.5 µm. The coatings were characterized using SEM/EDS, surface roughness analysis, and mechanical performance tests, including adhesion and wear assessments. Preliminary results indicate that substrate roughness plays a crucial role in the deposition process, affecting coating uniformity and thickness distribution. Unpolished substrates exhibit increased roughness values, leading to leading to uneven material deposition and less consistent thicknesses. Consequently, this highly influences the adhesion and wear behaviour of the coatings. Despite this, surface roughness does not appear to impact the presence of defects in the coating topography or affect the adhesion between coating layers.

Formability limits in thin-walled tubes with square cross section and L-section profiles

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Thin-walled structures are widely used in transportation and other industries due to their high strength-to-weight ratio and geometric versatility. While traditional manufacturing techniques like tube bending and end forming are common, emerging processes such as tube hydroforming (Ahmetoglu and Altan, 2000), incremental tube forming (Becker et al., 2014), and friction-spinning (Lossen et al., 2018) demand a deeper understanding of the tube structural formability, especially under complex loading conditions.
This study extends the current knowledge of formability limits beyond circular tubes to include thin-walled square tubes and L-section profiles, which exhibit distinct deformation behaviours due to their corners and increased resistance under axial compression. Established experimental methodologies for determining formability by necking and fracture, originally developed metal sheets, were successfully adapted to these new geometries using tensile and shear tests.
Additionally, a novel methodology was developed to evaluate formability limits governed by local buckling and applied for the first time to square and L-section profiles. The results, presented in principal strain space, validate the extended and newly proposed method, offering a more comprehensive framework for assessing the formability of non-circular thin-walled profiles.

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Internal Hole Quality Assessment in the Drilling of Thin CFRP/Al Multi-Material Stacks

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The joining of a metal and a composite made fiber metal laminates show a better global performance than using each of these materials separately, with increasingly more applications in several different industries, such as the aeronautical and automotive. The composites' higher strength-to-weight ratio, resistance to fatigue and corrosion, allied to the ductility, damage tolerance and thermal conductivity of metals, result in multi-materials with enhanced properties capable of resisting the excessive loads endured by the modern vehicles. Notwithstanding, drilling fiber metal laminates for mechanical connections required to join different components together stands as one of the main obstacles of this process. The need to cut through different materials at the same time added to the high abrasiveness characteristic of the composite fibres not only causes a several tool wear, but also compromises the holes' quality, with delamination being the most problematic issue. Following a previous study comparing the drilling of three-layered CFRP/Al fiber metal laminates of three distinct thicknesses, 4.5 mm, 2.4 mm and 0.9 mm using CVD diamond coated standard twist drills, this work focused just on the thinner one, as it revealed the presence of internal delamination in several holes, in contrast to the remaining configurations. A new experimental campaign with a narrower set of parameters was performed to identify the delamination starting point, which was established to be using feed values from 0.15 mm/rev to 0.20 mm/rev, being this the most impactful parameter in the internal hole quality. Furthermore, a gabari was designed to place a thermal camera below the stack, so that the temperatures generated on the exit side of the holes could be compared to the ones from the entry side recorded in the previous tests to also determine the thermal influence on the assessment of the hole quality in the fiber metal laminates drilling process.

A new methodology for controlled thickness in deformation machining

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Deformation machining constitutes a hybrid process resulting from the integration of incremental sheet forming and thin structure machining. This hybridization, which originated in the early 2000s, enables the production of complex geometries with thin wall sections while minimizing raw material usage. However, there is still a limited understanding of how these two technologies interact with one another, which hinders the possibility of tailoring the processing strategies to the characteristics of the final product, such as geometry and surface quality.

Under these circumstances, this work focuses on the development of a methodology that allows predicting and compensating the position-dependant thickness as a function of incremental forming parameters, such as tool diameter, and of the intended part geometry.

The experimental work was conducted on a CNC centre for machining the workpiece into a tailored blank and afterwards for defining the final part geometry by incremental forming. The tests were carried out on 6082-O aluminium alloy sheets with an initial thickness of 2 mm with the goal of obtaining variable axisymmetric geometries while achieving a final constant thickness of 1 mm.

Results show that the proposed methodology allows attaining parts with a constant thickness with deviations up to 10%. On the other hand, the deviations are smaller when the incremental forming stage is carried out at the same side of the tailored blank where the machining stage took place.

The proposed approach was validated through the fabrication of a prototype for an aircraft electrohydrostatic actuator housing, demonstrating the practical applicability of hybrid sequences based on deformation machining to produce complex, customer-oriented parts, namely for the aerospace sector.

Application of Stress scale factor approach to 316L stainless steel produced by powder bed fusion-laser beam

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Many engineering components in operation experience multiaxial loading conditions rather than uniaxial. It is well known that the understanding of such a state of stress remains a hot topic, and the models that have been proposed to address this state of stress are still unable to fully address all the factors that play key role in multiaxial fatigue failure. In this study, 316L stainless steel tensile and fatigue samples produced by powder bed fusion-laser beam (PBF-LB) were used. All samples were machined and subjected to stress relief at 700°/ 4h prior to the removal from the building platform.

To assess the quality of both tensile and fatigue samples a relative density measurement was obtained via Arquimedes method. As for fatigue sample, computed tomography scan (CT-scan) using Dragonfly software was also used. Additionally, a surface roughness measurement was conducted in the center of gauge length.

As for the fatigue testing, several loading paths such as uniaxial, torsional, proportional with varying stress amplitude ratio and non-proportional with 90º phase shift were considered. A stress scale factor (SSF) approach were later used to determine damage parameters and then to estimate fatigue life. As for the correlation between experimental predicted fatigue life, in general there was a good agreement with all results being within a scatter band of ±2.

EES III: Energy, Environment and Sustainability

Optimization of a Hydrogen and Natural Gas Blending and Injection Station

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Carbon neutrality has been a focus of significant attention in Europe, and progress is expected to be made by 2050. The natural gas sector, in particular, is one of the most significant contributors. Blending hydrogen with natural gas and utilizing existing natural gas pipelines is a short-term strategy that could help reduce carbon emissions. However, the main challenge with hydrogen in natural gas pipelines is its potential to cause hydrogen embrittlement (HE), which compromises the structural integrity of the pipelines. It is therefore necessary to reduce the high local concentration of hydrogen on the internal surfaces of pipelines by promoting uniform mixing. This study aims to develop solutions to optimise the injection and mixing of hydrogen in natural gas pipelines by means of numerical simulations (CFD) applied to different configurations of T-junctions. The mixing quality was then analysed using the coefficient of variation (COV). Hydrogen injection from the upper and underside natural gas pipelines was compared for different injection tilt angles. It was found that the underside injection results in better mixture homogeneity achieving COV values below 5% in most cases, although the buoyancy effects of hydrogen still create high local hydrogen concentrations that may induce HE of steel.

A double injection system is proposed to improve the blending. It was found that the new system reduces the distance needed to standardise the mixture and avoids direct contact between the hydrogen and the walls. In one case, a COV of 5% was achieved in 13*D* (roughly 9 m). However, applying this method does not guarantee good injection for small hydrogen fractions (< 20%) in the final mixture. The key to overcoming this obstacle is the horizontal double injection of a pre-mix of hydrogen and natural gas, which enables the production of homogeneous mixtures with reduced hydrogen fractions. Finally, all the solutions that were considered viable in terms of injection and homogeneity are presented.

Techno-economic performance analysis and environmental impact assessment of transporting hydrogen through pipelines

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In recent years, with the definition of European strategies that encourage energy transition, Green Hydrogen (GH2) has emerged as a potential alternative to tackle climate change and fossil fuel dependency. To consider Hydrogen (H2) a renewable fuel accountable for the targets set by the Renewable Energy Directive III, it must be produced from renewable energy sources according to additionality and temporal-geographical correlation criteria. Thus, the production of the 40 GW GH2 expected for the energy transition will necessarily be linked to favourable geographical locations with good climate conditions [1]. This will require the implementation of reliable transportation infrastructure [2].

Transportation of gaseous hydrogen by pipelines is seen as a cost-effective option as the volume of transported hydrogen increases. Several projects are currently being developed at national, regional and European levels to evaluate the feasibility of transporting GH2 by pipelines and to assess the performance of newly built and repurposed H2 pipelines.

For the construction or repurposing of hydrogen pipelines to be successful, it is essential to ensure that the infrastructure can transport the required energy volumes without significant cost increases, that life cycle emissions from both the transport system and the hydrogen itself are minimized, and that the pipelines can safely contain hydrogen to keep the risk of incidents acceptably low.

Although the influence of gaseous hydrogen on material properties such as ductility, fracture toughness and fatigue crack growth resistance has been extensively studied, there are still large variations in reported results [27]. The long-term behaviour of polymeric materials under hydrogen exposure is still not fully understood, highlighting the need for further research.

At the same time, it is essential to assess both the economic and environmental implications of different pipeline materials, as well as construction, operation, and end-of-life strategies. Such evaluations are critical not only to ensure technical feasibility and safety, but also to support the identification of the most sustainable solutions for hydrogen transportation by pipelines.

As new knowledge is produced, it must be integrated into updated codes and standards specifically designed for hydrogen pipeline operation.

Considering the challenges outlined, the present work will focus on answering the following research question:

How do techno-economic and environmental aspects affect the transport of green hydrogen through pipelines, taking into consideration different material selection, construction, operation, and end-of-life strategies?

Effect of Turbulence Models on Hydrogen Injection Flow Dynamics in Natural Gas Pipelines

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Blending hydrogen into existing natural-gas pipelines promises rapid decarbonisation but poses unique mixing and safety challenges due to hydrogen's low density and high diffusivity. Accurate turbulence modeling is thus critical for predicting concentration fields and assessing material compatibility. This dissertation investigates the impact of turbulence‑closure selection on flow and mixing performance in high‑pressure hydrogen‑natural‑gas transmission pipelines. Four RANS models (SST k‑ω, realizable k‑ε, standard k‑ε, standard k‑ω) were applied to three hydrogen mole fractions (25%, 20% and 15%) to assess how turbulence‑scale predictions (k, ε, ω) translate into eddy viscosity μt and, ultimately, mixture homogeneity quantified via Coefficient of Variation. For the 20% case, the Portuguese regulatory limit, a scale‑resolving LES‑WALE simulation provided a benchmark and revealed that RANS closures systematically overpredict near‑injector turbulent kinetic energy and mix more aggressively. Furthermore, inter‑model Root Mean Square Deviation analysis demonstrated that variability among RANS predictions grows markedly as hydrogen content decreases (mean deviation rising from 1.7% at 25% to 11.5% at 15%). LES transient results further captured time‑dependent Coefficient of Variation fluctuations (50‑80% near x/D = 3) that steady‑state and transient RANS cannot resolve. These findings identify the first 10‑15 diameters as a critical region for design and safety and underscore the necessity of rigorous turbulence‑model validation, through LES or targeted experiments, to ensure accurate, reliable, and safe integration of hydrogen into existing gas networks.

Intelligent identification of hydrogen trap information in temperature-programmed hydrogen desorption

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Thermal Desorption Spectroscopy (TDS) is a widely used technique for quantifying key characteristics of hydrogen-material interactions, such as diffusivity and trapping. However, one of the most critical challenges in TDS is the efficient and accurate extraction of meaningful hydrogen trapping information from TDS data. Therefore, a machine learning-based identification method for hydrogen trap information from TDS is proposed in this study. This approach allows for the rapid, accurate, and robust extraction of hydrogen trap density and binding energy from TDS, including both single-trap and distinct double-trap scenarios. TDS curves are first generated under various trapping conditions using the dimensionless Oriani model. These curves are then fitted with an Asymmetric Double-Sigmoid Function (ADSF), yielding six fitting parameters that serve as input features for the machine learning model. The corresponding hydrogen trap information including dimensionless binding energy and trap density, is used as the output. Once trained, the model can easily infer trap characteristics from unknown TDS data.

Evaluation of Different CO2 Capture Technologies - Life Cycle Assessment approach

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Mitigating climate change requires a dual strategy: reducing greenhouse gas emissions at their source and deploying technologies that actively remove CO_2 from the atmosphere. Carbon capture technologies are among the most promising solutions, increasingly recognized as essential for achieving global climate targets and net-zero pathways. Carbon Capture and Storage (CCS) enables the permanent sequestration of CO_2 in deep geological formations, while Carbon Capture and Utilization (CCU) repurposes CO_2 into value-added products such as synthetic fuels, polymers, and chemicals. Together, these approaches support emission reduction and the transition to a circular carbon economy. The potential of CCS and CCU is substantial: for example, CCS can significantly lower the global warming potential of coal- and gas-fired power plants when combined with advanced techniques such as oxy-fuel combustion or post-combustion amine scrubbing. However, their widespread adoption requires not only technological feasibility but also a robust understanding of environmental and economic implications across the full lifecycle. This study addresses these gaps through a review of Life Cycle Assessment (LCA) applications to CO_2 capture technologies, complemented by a specific case study. The objectives are fourfold: (i) to define the main Key Performance Indicators (KPIs) relevant to each stage of assessment; (ii) to conduct LCA studies comparing the environmental performance of innovative CO_2 capture pathways, focusing on thermal regeneration and electrochemical methods; (iii) to compile and structure an inventory dataset for evaluating these technologies; and (iv) to implement an integrated LCA assessing both environmental and economic performance of CO_2 capture within the cement industry. Special attention is given to emerging amine-based capture systems, which achieve capture efficiencies exceeding 95%. The results provide critical insights into environmental trade-offs and underscore the essential role of carbon capture technologies in enabling a sustainable, low-carbon future.

Investigating the Degradation Mechanisms of IrO2 Catalysts for PEM Water Electrolysis Using In-Situ Scanning Transmission Electron Microscopy

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Hydrogen production through water electrolysis is a critical process for the renewable energy transition. The efficiency and durability of the electrocatalysts used in proton exchange membrane (PEM) water electrolysis, particularly for the oxygen evolution reaction (OER), are central to advancing this technology. Iridium oxide (IrO_2) is one of the most effective catalysts for OER, but its high cost and limited availability hinder large-scale applications. This study aims to investigate the degradation mechanisms of IrO2 catalysts under real-world PEM electrolysis conditions using scanning transmission electron microscopy (STEM) techniques. Specifically, in-situ STEM will be employed to observe the structural and morphological changes of IrO_2 catalysts during electrochemical cycling. This technique will allow us to track particle migration, coalescence, Ostwald ripening, dissolution, and redeposition under working conditions. Key factors in this study involve selecting high-quality liquid cell chips (Indium Tin Oxide electrodes) and minimizing electron beam damage by employing low-dose imaging methods. Ultimately, this study allows developing the operating conditions for further research into developing cost-effective and stable electrocatalysts for hydrogen production, particularly under realistic electrochemical conditions that closely simulate those in large-scale PEM water electrolysis systems.

Moisture content of live and dead fine fuels and their relation to meteorological conditions and wildfire activity in the Central Region of Portugal (2000-2024)

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The Forest Fire Research Center of the Association for the Development of Industrial Aerodynamics (CEIF-ADAI) has maintained a fuel moisture sampling program at the Lousã Airfield since 1987, given the importance of live and dead fuel moisture content (LFMC and DFMC, respectively) in both wildfire research and operational applications.

While the moisture content of dead fuels can be reliably estimated from meteorological data and is widely used in operational fire danger systems, such as the Canadian Fire Weather Index System (CFWIS), and in fire behavior models, the integration of live fuels remains limited. This limitation stems partly from the physiological complexity of live vegetation and from the scarcity of long-term, species-specific datasets in Mediterranean ecosystems. Using data from 2000-2024 (June to September, the most critical wildfire period), this study analyzes the fuel moisture content (FMC) in surface vegetation, including live shrub foliage (*Calluna vulgaris* and *Chamaespartium tridentatum*), as well as dead leaves or needles from *Pinus pinaster* and *Eucalyptus globulus* lying on the forest floor. Our initial hypothesis was that FMC variables, both live shrub foliage and dead fuels, are associated with fire activity, particularly for events exceeding 100 ha and 500 ha. In parallel, we explored associations with CFWIS indices (well-established international meteorological indicators) as a reference framework.

Despite the well-known role of dead fuels in fire occurrence, live shrub foliage showed consistent and strong associations with fire activity and large wildfire events, with patterns comparable to those of the most relevant CFWIS indices. These findings suggest that incorporating or improving LFMC estimates, whether from field data, meteorological models, or remote sensing, could improve long-term seasonal danger assessments and short-term fire behavior predictions.

BIO II: Biomechanics

Development of biomimetic polyvinyl alcohol/ polyethylene oxide/ lysine membranes functionalized with ibuprofen and salicylic acid for application in the regeneration of skin wounds

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Skin as the largest organ in the human body, acts as a protective barrier, regulates body temperature and has a crucial role in homeostasis. Extensive skin lesions, such as chronic wounds, surgical wounds or burns compromise its structure and function, leading, in some cases, to life threatening situations. To reestablish, as soon as possible, skin features, clinicians have been using grafts (autografts, allografts or xenografts). Although, the limited availability of donor sites, associated morbidity and long periods of patients' hospitalization, demand for new dressings capable of protecting the wound and promoting healing.

In the area of Tissue engineering, polymeric biomaterials that mimic the structure of native skin and are able to promote tissue regeneration have been developed and characterized. Herein, a nanofibrous membrane composed of polyvinyl alcohol (PVA) polyethylene oxide (PEO) and lysine (Lys) was developed and subsequently functionalised with ibuprofen (IBP) and salicylic acid (AS). This approach aims to grant the membranes anti-inflammatory and antimicrobial properties, which are required for improving the wound healing process

The produced membranes displayed uniform morphology and adequate porosity. In vitro tests showed that membranes enable cell proliferation, without inducing acute cytotoxic effects. Surface electron microscopy was utilized to assess the presence of Staphylococcus aureus and Escherichia coli on the surface of the membranes. In this way, the produced membranes appear to be promising for application as wound dressings, offering promising potential for skin regeneration.

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Development of Melt-Electrowritten Mesh Implants with Integrated Antistatic Properties for Hernia Repair

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Hernia is a physiological condition that significantly impacts patients' quality of life, where there is an organ prolapse through the wall of the cavity that is normally contained, due to a weakness or opening, mainly of the abdominal wall. The standard surgical approach involves reinforcing the abdominal wall with specialized mesh implants. Although generally effective, this method is associated with several postoperative complications, including pain, infections, inflammation, tissue adhesions, and in some cases, the necessity for revision surgeries. According to the U.S. Food and Drug Administration (FDA), hernia recurrence rates can be as high as 11%, surgical site infections occur in up to 21% of cases, and chronic pain is reported in up to 68% of patients. These data highlight the critical need for advancements in mesh design and performance to minimize such outcomes.

In this study, a preliminary innovative melt-electrowritten mesh with antistatic properties for hernia repair is presented. Melt Electrowriting is an emerging fabrication method that enables precise placement of microfibers, closely replicating the structural features of the native extracellular matrix. The study investigated the effect of incorporating the antistatic agent Hostastat ® FA 38 (HT) at concentrations of 0.03, 0.06, and 0.1 wt% on the fiber diameter and mechanical properties of Polycaprolactone (PCL) meshes. The addition of HT reduced fiber diameter by 14–17%, 39–45%, and 65–66%, depending on the mesh geometry (square or sinusoidal, both with a 1.5 mm pore size). The decrease in fiber diameter was associated with enhancements in tensile strength and Young's modulus, as verified by uniaxial tensile testing. Comparisons between PCL/HT and pure PCL meshes with similar diameters and geometries confirmed the enhanced mechanical properties of PCL/HT meshes. Cytotoxicity tests, using the resazurin assay, indicated no cytotoxic effects at any HT concentration. Additionally, no significant variation was observed between the two sterilization techniques used (Ethanol + UV vs. UV only). These findings demonstrate that incorporating HT into PCL meshes produces thinner, more stable filaments with improved mechanical performance and no cytotoxicity, making them a promising material for applications such as hernia repair. Future research focusing on the interaction between polymers and additives may further enhance the mechanical and biological performance of these materials.

Production of 3D printed scaffolds coated with Gelatin and Tree tea oil for future application in bone tissue regeneration

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The ageing of the worldwide population is closely related to the increase in the incidence of fractures, bone defects and other diseases that affect bone tissue. Such health conditions demand treatments that are capable of fully reestablish the structure and functions of the bone (1). In the area of Tissue Engineering, researchers have been studying new materials that are capable of overcoming the limitations of conventional treatments (bone grafts) (2). Among the materials studied, sodium alginate (SA) and tricalcium phosphate (TCP) have been widely used for the manufacture of scaffolds. However, to prevent microbial growth, i.e. reduce the risk of occurrence of infection at the site of the bone defect, scaffolds have been functionalized with different antimicrobial agents (3). In this regard, tree tea oil (OTT) has been attracting a great interest, since it is a natural antimicrobial agent. Herein, a Fab@Home 3D-Plotter printer was used for scaffolds production. To accomplish such purpose, a formulation composed of sodium (SA) and tricalcium phosphate (TCP), coated with Gelatin (Ge) and OTT was used. The produced 3D scaffolds display rough surfaces, which are essential for cell adhesion. Mechanical data showed that the produced scaffolds have a superior compressive strength and Young's modulus in comparison to native trabecular bone features. The scaffolds were able to support cell adhesion and metabolic studies were used to investigate their cytocompatibility. Scaffolds coated with Ge and OTT prevented Escherichia coli and Staphylococcus aureus adhesion at scaffolds' surface and their proliferation. These data demonstrate that the produced scaffolds display properties that make them promising candidates for their future application in bone regeneration.

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Mechanical Suitability of Biodegradable Meshes in Pelvic Organ Prolapse Treatment

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Pelvic Organ Prolapse (POP) affects a significant number of women globally, primarily due to the weakening of pelvic floor structures. While synthetic meshes are commonly used in surgical repair, they are associated with complications such as erosion and chronic pain. Consequently, biodegradable meshes have emerged as promising alternatives, offering improved biocompatibility and a reduced risk of long-term complications. This study evaluates the mechanical performance of biodegradable polycaprolactone (PCL) meshes through experimental testing and computational modeling to support their use in POP repair.

The aim of this study is to characterise the mechanical behaviour of PCL meshes in comparison to native vaginal tissue, with a focus on how mesh geometry influences performance. Two mesh designs, quadratic and cross-shaped, were fabricated using melt electrowriting (MEW) with a filament thickness of 240 μm. Mechanical testing included uniaxial tensile and ball burst tests on both the meshes and sow vaginal tissue. Finite element models of the ball burst tests were developed in Abaqus/Explicit to simulate tissue-mesh interaction and validate the predictive accuracy of the models.

The results from the ball burst tests indicated that PCL meshes enhanced maximum force resistance by 14% to 20% compared to native tissue, with the cross-shaped mesh outperforming the quadratic design by up to 30%. Numerical simulations closely matched the experimental data, with discrepancies of 6% for native tissue, 7% for standalone meshes, and 14% for mesh-reinforced tissue. These findings confirm the utility of computational modeling in accurately predicting mechanical responses and guiding future mesh design.

In conclusion, biodegradable PCL meshes with optimized geometries offer a viable alternative to traditional synthetic implants for POP treatment, providing enhanced mechanical support and the potential for fewer postoperative complications. Furthermore, validated simulation tools support preclinical evaluation, potentially reducing the need for animal testing. Future research should focus on long-term in vivo studies to assess degradation, biocompatibility, and clinical efficacy.

Experimental evaluation of intended decay of mechanical properties in iron lattice materials for biodegradable implants

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The use of biodegradable metals as temporary bone implants has become appealing in recent years. Within such metals, iron has excellent biocompatibility properties but exhibits a slow degradation rate and a considerably higher stiffness than bone. The use of porous structures like lattices, instead of bulk material, has been proposed as a strategy to reduce stiffness and to increase the degradation rate in the case of iron. The present work aims to study the effect of degradation/corrosion on the compression properties of lattice structures made of rhombitruncated cuboctahedron (RTCO) unit cells with relative densities of 10%, 35%, and 65%. Experiments were conducted where samples were immersed in simulated body fluid (SBF), and their weight loss and compression mechanical properties were measured 7, 14 and 21 days after immersion. The mechanical properties were obtained through compression tests on three samples for each immersion time, one for each relative density considered in the study. Additionally, three control samples of each relative density that were not immersed in SBF were tested in the same conditions. Mass loss after 21 days (3 weeks) was at most 2.9%. Estimating the experimental mass loss for 4 weeks, with a linear extrapolation, one obtains a lower value when compared with the previous numerical works that report 5.8-8.9% after 4 weeks [1]. The stiffness reduces by a maximum of 24.5% for the samples with a relative density of 35% and a minimum of 7.5% for the samples with a relative density of 65%. The stiffness reduction is accompanied by a decrease in yield stress, of a similar magnitude. These results are consistent with a previous study that considers dynamic immersion over 4 weeks, which reports slightly higher values of stiffness reduction, of about 40% on average [2].

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On the Analysis of the Hemocompatibility of 3D-Printed ABS

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Additive manufacturing (AM) has gained increasing relevance in biomedical engineering due to its design flexibility, cost-effectiveness, and capability to rapidly produce complex geometries. Especially, for blood-contacting devices, AM offers the potential to accelerate the development of novel solutions and to fabricate components for *in vitro* and lab-scale applications. Despite these advantages, few studies have investigated the applicability of AM in this context. Specifically, research on the hemocompatibility of 3D-printed materials, such as Acrylonitrile Butadiene Styrene (ABS), under both static and dynamic blood-contact conditions is limited.

With that in mind, this study investigates the hemocompatibility of ABS components fabricated via material extrusion. Given that acetone smoothing is a post-processing procedure known to reduce the surface roughness and improve watertightness of 3D printed ABS, which are two critical factors for blood-contact applications, the effects of acetone post-processing are also evaluated. For this purpose, two commercial neutral ABS filaments, including one of medical grade, are assessed and compared. The comparative analysis encompasses a study of the dimensional accuracy, surface roughness, and wettability, alongside standardized hemocompatibility assays performed under static conditions (ISO 10993-4), including hemolysis, thrombogenicity, platelet adhesion, and leukocyte activation.

Overall, no significant differences were observed between the two ABS filaments. Both materials were non-hemolytic, with hemolysis values below the 2% threshold. Short-term thrombogenicity assays demonstrated clot masses substantially lower than those of the positive control, supporting the suitability of ABS for dynamic applications. However, prolonged exposure appeared to indicate a tendency toward thrombogenicity. Acetone post-processing significantly reduced surface roughness and improved sealing but did not affect overall hemocompatibility, including hemostasis-related outcomes. These findings are particularly relevant, as they reveal that acetone curing can be safely used to improve surface roughness and watertightness of 3D-printed ABS without compromising its hemocompatibility.

The results support the potential application of 3D-printed ABS in blood-contacting contexts, particularly for *in vitro* and lab-scale devices, providing an alternative to commonly used materials, which are more prone to leakage or exhibit higher surface roughness. Nonetheless, precautions are necessary to mitigate thrombogenicity risks, either by limiting prolonged blood exposure or by implementing appropriate anticoagulation strategies.

ISC II: Intelligent Systems and Control

A Requirements-Driven Control Architecture for Coordinated Robotic Ocean Surveys

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Ocean surveys must balance trade-offs between temporal and spatial resolution to capture phenomena that span multiple spatial and temporal scales. Autonomous platforms now make distributed and cost-efficient observation possible; however, missions are still programmed in terms of low-level motion commands such as waypoints and maneuvers. This creates a semantic gap between high-level scientific requirements and low-level vehicle execution, leaving requirements such as resolution, coverage, and synopticity often neither preserved nor verifiable during operation.

To address this gap, we propose a requirements-driven control architecture. Scientific goals are expressed as sampling requirements at mission, team, and vehicle levels. This ties the survey design directly to the data that it is meant to produce. A specification layer formalizes these requirements and provides an interface to translate them into survey plans and vehicle tasks.

By designing surveys around high-level sampling requirements instead of low-level motion-related commands, the architecture keeps scientific objectives central throughout planning and execution. In our early work, we use surveys of oceanic fronts to explore how the architecture can simplify planning, improve coordination, and support synoptic measurements, needed to capture frontal dynamics with appropriate resolution.

Quadrotor Trajectory Tracking: An Almost Global Full-State Solution

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This paper presents a novel control strategy for underactuated quadrotors, unifying position and attitude dynamics into a single full-state feedback framework. Departing from conventional hierarchical methods, the approach redefines the complete system as a triple integrator with dual inputs, linearly coupled to the attitude error, while angular velocity and thrust serve as direct control inputs. A nonlinear transformation renders the complete system dynamics linear time-invariant (LTI), enabling the application of Linear Quadratic Regulator (LQR) optimisation for exponential stability within a prescribed linear region. Key to this formulation is a prescribed bounded attitude error definition that ensures almost global convergence while avoiding singularities inherent to $\mathbb{S}^2$ representations. The resulting controller explicitly accounts for the feedback interconnection term, eliminating reliance on nested loops or backstepping. Asymptotic stabilization under input saturation is rigorously validated through numerical simulations, showcasing its potential and effectiveness.

Benchmarking CNN Architectures for Robust Surface Defect Detection Across Multiple Domains

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Accurate Surface Defect Classification is vital in industrial quality control. While Deep Learning models have shown strong performance on individual datasets, few studies benchmark multiple architectures under consistent conditions across varied surface defect datasets. So, a critical gap remains in evaluating how different deep learning models perform under consistent training conditions across diverse, real-world defect datasets. Most existing studies focus on a limited number of architectures and often employ varying preprocessing pipelines or inconsistent evaluation protocols, which hinders direct comparison. Moreover, there is limited discussion regarding the computational trade-offs between accuracy and efficiency - an important consideration for deployment on edge devices in manufacturing environments, where real-time inference and limited resources are crucial.

These limitations motivate the present work: a systematic, multi-dataset, and cross-architecture comparison that not only quantifies performance but also highlights trade-offs between model complexity, inference speed, and classification robustness. By addressing these gaps, this research aims to bridge the divide between research-driven accuracy and the practical feasibility required for industrial deployment in surface defect detection and classification.

This work evaluates convolutional neural networks, a vision transformer and a detector (YOLOv12) on five public benchmarks: NEU-DET, X-SDD, KolektorSDD2, DAGM, and MTDD.

All models were trained using the same pipeline and assessed with standard classification metrics (accuracy, precision, recall, F1-score) and training time.

ResNet50 achieved the highest average F1-score, particularly on complex datasets, while MobileNetV2 and SuperSimpleNet provided strong accuracy with lower computational cost. The results offer practical insights for selecting models based on accuracy-performance trade-offs in real-world deployment. Future work involves exploring domain adaptation, lightweight optimization, and support for real-time surface inspection.

Robust Global Exponential Attitude Tracking on SO (3) via Optimal MRP-Based Hybrid Feedback

Luís Martins[1]; Carlos Cardeira[1]; Paulo Oliveira[1]
[1]IDMEC

This paper presents an innovative, robust attitude tracking controller for fully actuated rigid bodies.
The approach relies on the modified Rodrigues parameters (MRP) description, which is a double covering of the three-dimensional rotation group SO(3), and the feedback linearization technique to formulate a Lyapunov-based quadratic programming problem. The resulting optimal controller ensures the exponential decay of the attitude tracking errors with minimum control effort and operates within a hybrid system structure to overcome the topological obstructions of the rotation group, rendering the attitude tracking dynamics globally exponentially stable on the MRP space. By combining this MRP-based optimal controller with a hybrid dynamic path-lifting mechanism, this novel approach yields an equivalent tracking result on SO(3). Furthermore, the resulting closed-loop system is nominally robust to perturbations, including external disturbances, parameter variations, or measurement noise. Numerical simulations demonstrate the performance and efficiency of the optimal hybrid strategy.

Cost-Effective AUV Navigation

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Autonomous Underwater Vehicles (AUVs) extend scientific access to hostile and remote marine environments, from abyssal trenches to habitats beneath ice, by operating untethered for hours to weeks. Their operational costs remain high: limited endurance, reliance on support vessels, expensive sensors, and risk of vehicle loss constrain mission frequency and spatial coverage. Navigation is central to autonomy, and Doppler Velocity Logs (DVLs) are the principal solution for limiting inertial drift, but they are costly and fragile in many environments (high altitudes above the seabed, absorbent bottoms, turbid water). This work addresses the challenge of reducing AUV dependence on expensive velocity sensors while preserving navigation accuracy and gaining environmental situational awareness.

We propose a machine learning framework that uses a multi-task model to estimate vehicle velocity and local ocean currents from onboard inertial data, and a federated learning (FL) protocol that shares knowledge across a heterogeneous fleet so DVL-equipped AUVs transfer observability to less-instrumented agents. The first component targets single-vehicle operation in DVL-denied conditions by providing velocity estimates that approach the performance of DVL. The second multiplies fleet capability by enabling distributed mapping of currents and improving dead-reckoning for vehicles that lack direct velocity sensors.

The core model is a temporally aware network trained to map sequences of high-rate inertial measurements together with DVL readings to two outputs: the 3D vehicle velocity (vehicle frame) and the local water velocity (georeferenced). Learned velocity estimates are used as pseudo-measurements inside classical navigation filters, preserving estimator interpretability.

To scale beyond single vehicles, we embed the model within a federated learning framework. Observations from DVL-equipped AUVs contribute to sensor-limited agents, incorporating shared model updates and local adaptation, fleet members can bound dead-reckoning drift and extend submerged operation time without an absolute positional fix. This collaborative phase also accumulates distributed current estimates over mission areas, enabling wide-area, fleet-scale oceanographic sensing while respecting bandwidth and autonomy constraints. The approach turns heterogeneous fleets into distributed sensing networks that collectively improve navigation and reveal insights into ocean currents.

By reducing reliance on costly DVL sensors and leveraging cooperative sensing, the proposed framework can lower the barrier to high-fidelity ocean observation. Improved dead-reckoning increases survey spatial resolution, and fleet-scale current maps provide environmental context for planning and science goals. These advances allow AUV deployments to be more frequent, longer, and have wider space surveys, thereby accelerating marine research and operational applications.

Trajectory Tracking Control for Sounding Rockets via Adaptive Feedback Linearization

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Sounding rockets are instrumental platforms to provide cost-effective, rapid access to space, and to validate new technologies prior to orbital flight. In face of increasingly demanding mission scenarios, focusing on reusability and reconfigurability, adaptive and global control solutions are needed to track different trajectories in large flight envelopes, which may be generated in real-time using online guidance methods. In this work, a pitch plane trajectory tacking control solution for suborbital launch vehicles is derived relying on adaptive feedback linearization. Initially, the 2D dynamics and kinematics for a single-nozzle, thrust-vector-controlled sounding rocket are obtained for control design purposes. Then, an inner-outer control strategy, which simultaneously tackles attitude and position control, is adopted, with the inner-loop comprising the altitude and pitch control and the outer-loop addressing the horizontal (downrange) position control. Feedback linearization is used to cancel out the non-linearities in both the inner and outer dynamics, reducing them to two double integrators acting on each of the output tracking variables. Uncertainty is considered when canceling the aerodynamic terms and is estimated in real-time in the inner loop via adaptive backstepping. More precisely, making use of Lyapunov stability theory, an adaptation law, which provides online estimates on the inner-loop aerodynamic uncertainty, is jointly designed with the output tracking controller, ensuring global reference tracking in the region where the feedback linearization is well-defined. The zero dynamics of the inner-stabilized system are then exploited to obtain the outer-loop dynamics and derive a Linear Quadratic Regulator (LQR) with integral action, which can stabilize them as well as reject external disturbances. In the outermost loop, the estimate on the correspondent aerodynamic uncertainty is indirectly obtained by using the inner loop estimates together with known aerodynamics relations. The resulting inner-outer position control solution is proven to be asymptotically stable in the region of interest in terms of pitch angle, i.e, in the upper region of the unit circle excluding the horizontal orientation. Finally, the control strategy is implemented in a Matlab/Simulink simulation environment composed by the non-linear pitch plane dynamics and kinematics model and the environmental disturbances to assess its performance. Using a single-stage sounding rocket propelled by a liquid engine as reference vehicle,

different mission scenarios are tested in the simulation environment to verify the adaptability of the proposed control strategy. Preliminary simulation results are satisfactory, given that the controller is able to track the requested trajectories while rejecting external wind disturbances. Furthermore, the need to re-tune the control gains in between different mission scenarios is minimal to none.

EES IV: Energy, Environment and Sustainability

Environmental and Economic Benchmarking of Municipal Waste Management through Waste-to-Energy Techniques

Ana Ramos
INEGI

Waste production is a significant challenge faced by societies worldwide, driven by factors such as population growth, urbanization, industrialization, and changes in consumption patterns. Municipal solid waste (MSW), which includes household, commercial, and institutional waste, constitutes a significant portion of the waste stream. The waste management problematic encompasses various interconnected issues, including waste generation, collection, transportation, treatment, and disposal. Inefficient waste management practices can exacerbate environmental degradation, contribute to climate change through greenhouse gas emissions, and pose risks to human health and ecosystems. Effective waste management is crucial to mitigate these however, many regions struggle with inadequate waste management infrastructure, leading to issues such as improper disposal, illegal dumping, pollution of land, water, and air, and threats to public health. This work compares the environmental and economic impacts of three waste management techniques, namely incineration, gasification and plasma gasification, a case study for the MSW produced in Portugal in 2022 being presented, following ISO 14040/44.

The preliminary environmental results show that gasification-based techniques are more proficient than traditional incineration regarding environmental impacts; global warming potential, acidification potential, terrestrial ecotoxicity potential and photochemical ozone creation potential are the categories where more benefits are achieved. Acidification potential, ozone depletion potential and photochemical ozone creation potential depict environmental savings for all the waste management techniques considered. The cost assessment has shown that for the specific MSW composition appraised, incineration seems to be the most profitable technique to produce energy, providing a cost/kW below the actual grid price for Portugal (c€ 12 vs c€ 15, approximately). It would be interesting to compare this for different countries and distinct MSW composition, as for certain distinct outcome would be achieved. Gasification-based techniques depict higher costs, however, it is essential to note that these values are not definite or stationary; these may vary according to several factors, such as the time-value of money, cost of opportunity, national context, etc.

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Development of a HTHP design tool for industrial waste heat recovery system integrated with a two-phase variable geometry ejector and IHX using natural

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The growing demand for thermal energy in industrial sector translates into an increase in waste heat rejection. High-temperature heat pumps (HTHPs) offer a promising technological solution by enabling the recovery, and reuse, of waste heat through its temperature upgrade, with a relatively small amount of external energy requirement. However, the demand for high temperatures associated to many industrial processes represents a technological challenge.

This numerical study evaluates HTHP performance with the integration of a two-phase variable geometry ejector (VGE) for expansion work recovery and an internal heat exchanger (IHX), considering different working fluids and system configurations. The contemplated VGE technology allows spindle and primary nozzle exit position (NXP) adjustments.

Numerical models were developed, in EES software, to predict HTHP performance indicators such as COP, establish operation maps, and also function as a design tool for system components. The models are based on the application of mass and energy conservation principles for the individual system components and for VGE cross-sections, applying real gas thermodynamic properties. Simulations were conducted for a small-scale prototype unit with an assumed minimal heat output of 20kW at 130ºC and with a temperature lift up to 60ºC.

Five natural working fluids were compared and the results showed that R601 performed well for the considered operating range. For R601 and a temperature lift of 60ºC, it was found that VGE integration reduced compressor electrical consumption by a 15% (COP=3.1) and compressor flow rate by 23%, with the required compressor flow rate showing reduced sensitivity to operating conditions. These findings highlight that the integration of a VGE into the HTHP systems is highly beneficial both in terms of performance and operation stability.

Understanding Energy Efficiency Barriers and Drivers in the Portuguese Water Sector: Upstream and Downstream Perspectives

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The urban water sector plays a pivotal role in modern society and is closely aligned with the United Nations Sustainable Development Goals by providing essential services like affordable drinking water and safe wastewater treatment. However, these services are highly energy-intensive, contributing significantly to municipal energy costs and greenhouse gas emissions. Global projections indicate rising energy demand in the sector, driven by population growth, urbanization, non-traditional water production methods such as desalination and reuse, higher contaminant loads, and increasingly stringent regulatory standards.

Given the water sector's heavy reliance on energy, energy efficiency has been fostered to enhance economic and environmental performance, mirroring trends from other sectors. However, despite the admittedly high energy efficiency potential in the sector, in conjunction with the significant pressure and incentives to implement energy efficiency and sustainability initiatives, many cost-effective investments remain unrealized and research into the barriers and drivers influencing energy efficiency in the water sector remains scarce. This situation constrains the design and adoption of better strategies and policies while inhibiting proper understanding of their development on the ground, their level of success, or the reasons for many energy efficiency investments not being undertaken.

By conducting questionnaires to employees from different areas and departments of Portuguese water and wastewater utilities, this study addresses this gap by comprehensively analyzing the differences in barriers and drivers to energy efficiency and in priorities for the next decade between upstream and downstream utilities. The results reveal that, for upstream utilities, the definition and implementation of a long-term energy strategy that permeates the various structural and organizational levels, driven by a legal and regulatory framework, is a differentiating element for success. In turn, downstream utilities favor economic drivers, such as dedicated financing mechanisms and tax incentives.

These findings highlight that the definition of energy and sector-oriented policies must consider and be adapted to the distinct characteristics and realities of upstream and downstream utilities to leverage energy efficiency adoption. By demonstrating the need to develop subsector-specific, evidence-oriented, and adaptable interventions and policy frameworks to promote sustained energy efficiency improvements across the water sector, this work provides crucial guidance for policymakers, regulators, and utility managers.

Trends, Gaps, and Methodological Challenges in Kinetic Modeling of Biomass Torrefaction: A Systematic TGA Review

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Torrefaction transforms heterogeneous biomass into a solid biofuel rich in carbon and energy, making it more suitable for gasification and co-firing. Thermogravimetric analysis (TGA) is a key experimental method for examining the decomposition kinetics of this process, providing critical data for reactor design and optimization. The creation of reliable kinetic models from TGA data is required for scaling torrefaction to industrial use.

The field uses a variety of often inconsistent modeling approaches, creating a need to map trends and identify gaps. Our study presents a PRISMA-guided systematic review and bibliometric analysis of 77 peer-reviewed articles (2019–2024). Research peaked in 2023, with China (32%) and the United States (18%) accounting for the majority of contributions. Thematic analysis shows a strong focus on conventional feedstocks—**woody biomass (36%)** and **agricultural residues (30%)**—while non-traditional species remain notably underrepresented. Model-free isoconversional techniques are widely used in more than 50% of research. A crucial finding is that over 45% of studies rely solely on statistical fit (R^2) for validation, with limited cross-model benchmarking. This risks model-dependent kinetic parameters that compromise robustness and restrict industrial applicability. Advancing the field requires a shift toward standardized multi-model validation protocols and expanding research to incorporate a wider range of biomass feedstocks to develop reliable kinetic models for commercial bioenergy production.

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Biomass combustion using a transient state approach

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For many decades, industries worldwide have relied heavily on fossil fuels as their dominant energy source. While effective in meeting growing energy demands, this dependence has led to severe environmental consequences, including greenhouse gas emissions, global climate change, and the depletion of finite resources. To address these challenges, researchers have turned to renewable energy alternatives, with biomass emerging as one of the most promising candidates. Biomass can be converted into useful energy through various thermochemical technologies, including combustion, gasification, and pyrolysis. However, these processes typically require expensive equipment and present operational difficulties related to storage, handling, and efficiency.

Computational fluid dynamics (CFD) has become an increasingly valuable tool for studying biomass combustion. Compared to experimental approaches, CFD provides a cost-effective and flexible means to analyze complex conversion mechanisms, offering insights that can lead to performance optimization. Nevertheless, combustion modeling is highly challenging due to the interplay of fluid mechanics, heat transfer, mass transport, and chemical kinetics.

This study employs CFD to investigate biomass combustion under controlled operating conditions. Simulations were conducted in Ansys Fluent 2024 R2, modeling a two-dimensional turbulent flow within a combustion chamber. The combustion process was represented using species transport with volumetric reactions, and turbulence–chemistry interactions were accounted for through the eddy dissipation model. Three reaction mechanisms (one-step, two-step, and four-step) were implemented to examine their influence on combustion behavior.

The analysis focused on the temporal and spatial evolution of key parameters, including temperature, velocity, turbulence intensity, and the mass fractions of wood and H_2O. Results show that, across all reaction mechanisms, velocity and turbulence reach their peak values in the early stages of combustion and gradually decline as the process evolves. Temperature increases rapidly at the beginning of the reaction and then stabilizes, showing minimal variation in later stages. Species mass fractions follow a similar pattern: initial fluctuations are observed, but they converge toward nearly constant values over time. Spatially, the highest mass fraction values are consistently located in the lower half of the combustion chamber. Furthermore, the behavior of wood and H_2O mass fractions exhibits a clear inverse relationship as the solid biomass decomposes, its fraction decreases while water vapor is simultaneously generated, leading to an increase in H_2O.

Valorization of Plastic-Biomass Mixtures in Co-Gasification: Simulation and Performance Assessment Using Aspen Plus®

Matheus Oliveira[1]; Abel Rouboa[1]; Eliseu Monteiro[1]; Ana Ramos[2]

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The continuous increase in urban and agricultural solid waste demands sustainable energy conversion solutions. Co-gasification of lignocellulosic biomass with plastic waste emerges as a promising alternative, enabling simultaneous valorization of urban waste and clean energy production. This study explores the hypothesis that adding plastics (PET, PE) to biomass can enhance hydrogen (H_2) and carbon monoxide (CO) yields in syngas while maintaining stable operation. A 24 kWe gasifier was modeled in Aspen Plus® to simulate co-gasification of agricultural residues and PET. Validation against experimental data showed syngas composition predictions within ±5% for CO, CO_2, and CH_4, with a maximum deviation of 4.4% for H_2. Simulations indicate the optimal point for PET additions for increase H_2 yield by up to 12%, while tar content remains controlled. The results highlight the feasibility of optimizing feedstock mixtures to maximize energy production, providing guidelines for pilot and industrial-scale operation. This approach integrates materials science, computational modeling, and circular economy principles, emphasizing co-gasification as a sustainable energy solution.

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Balancing beef: a physics-based multi objective framework for profit-sustainability trade-offs in beef production

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The livestock sector emits more than 7 Gt of CO_2-eq every year, which represents 15% of all anthropogenic greenhouse gas emissions. Cattle are responsible for 65% of emissions in the sector, with beef being the product with the largest contribution. Reducing the emissions of the sector through sustainable policies will likely have a negative impact on the economic performance of producers. If climate goals are to be achieved in a socially and economically sustainable way, stakeholders need an integrated approach to analyze how environmental and economic objectives interact.

Here, we present a multi-objective optimization framework for beef cattle production that captures the trade-offs between sustainability and profitability when choosing a slaughter time. We develop an animal model for Angus cattle based on Dynamic Energy Budget (DEB) theory, a bioenergetic model that is consistent with physical laws and has been used to model thousands of species. DEB models capture the entire lifecycle of an organism, allowing the framework to track growth, feed intake, feces and urine production, as well as methane emissions from birth to slaughter and under varying conditions. The model is calibrated with literature data and is consistent with IPCC emission factors.

Using genetic algorithms, we determine the optimal slaughter time that maximizes profit and minimizes environmental impacts. We resolve the complete Pareto frontier of profit and sustainability outcomes and analyze the reasons, both economic and at the animal level, that originate the trade-offs. Furthermore, we explore carbon pricing scenarios by substituting the sustainability goal with carbon taxes.

By integrating physics-based modelling within an optimization framework, the proposed approach provides a coherent basis for evaluating mitigation strategies and for the design of incentives that balance both sustainability goals and farm profitability.

SMS III: Structures and Mechanical Systems

Automatic Aircraft Parametric Shape Generation for Design Optimization

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The traditional aircraft design process is a fundamentally complex, resource-intensive, and iterative endeavor, often subject to time and computational resources constraints that limit the comprehensive exploration of the available design space. This work presents an advanced parametric design methodology focused on key aircraft components, namely wing and fuselage bodies. The main contribution is the automatic generation of aerodynamic surfaces, coupled with multi-fidelity aerodynamic simulation tools and optimization algorithms, to significantly enhance the aircraft design engineering capabilities. Not only are the generation algorithms detailed but also the underlying data storage schema for wings and fuselages are described. While the generation tools are powerful, allowing for a vast range of topologies from a reduced number of high-level design parameters, the true leverage is derived from the parametric data structure chosen to describe the bodies. Therefore, focus is given on the parametric definition of the generated aerodynamic surfaces using linear piece-wise descriptions, which both simplify the development of the algorithms and, critically, enhance the capability for direct geometric manipulation. The automation of this design-and-analysis workflow not only drastically shortens the conceptual and preliminary design phases but also empowers engineers to uncover innovative design solutions that might be overlooked in a conventional process. The resulting integrated design framework, that guarantees robust and accurate geometry generation, allows for a multitude of design variants to be systematically studied. This methodology accelerates the design cycle, by facilitating and reducing the cost and time associated with gathering high-fidelity aerodynamic data at early design stage, or to extend the design space exploration through the usage of low-fidelity data, thus mitigating downstream risks. Ultimately, this work establishes an effective and foundational approach for creating a comprehensive, integrated framework suite dedicated to modern aircraft design. The future prospects for this approach are considerable, as its principles of simplifying design complexity are directly applicable to other critical fields of aircraft engineering, including structural optimization and full-scale multidisciplinary design optimization.

A Systematic Review of Cabin Noise Control Strategies for VTOL Aircraft

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In response to increasing urbanization, the electric mobility trend is driving the development of vertical take-off and landing (VTOL) aircraft, which aim to alleviate on-ground urban congestion by enabling point-to-point transportation of people and goods. Current research on VTOL aircraft has primarily focused on safety and control operations, aerodynamics, and aeroacoustics. However, cabin noise remains unexplored despite playing a critical role in the safety, comfort, and health of pilots and passengers. To address this crucial topic, this study presents a systematic review of cabin noise research on conventional propeller- and rotor-driven aircraft, along with emerging aeroacoustics investigations on VTOLs. The aim was to identify opportunities and challenges that can inform the unique requirements for noise control in VTOL cabins. The literature revealed the importance of first characterizing the noise sources and determining the factors contributing to cabin noise before implementing mitigation strategies. Particularly in VTOLs, cabin noise is highly case-specific, depending primarily on the type of propulsion system, rotor configuration, and cabin design. Among the various approaches to mitigate cabin noise, two strategies emerge as particularly promising for VTOL applications. First, the early-stage development of VTOLs provides a unique opportunity to address noise directly at the sources through aircraft design modifications. Second, recent advancements in acoustic materials have enabled active strategies to be integrated within passive solutions, offering noise mitigation at the transmission path across a broad frequency spectrum.

Low Reynolds UAV Airfoil Adjoint-Based Optimization with SA-BCM Transition Model

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High-fidelity optimization frameworks have significantly advanced aerodynamic design by enabling systematic performance improvement across complex geometries and multiple operating regimes. These frameworks leverage Computational Fluid Dynamics (CFD) solvers to explore extended design spaces, thereby approaching theoretical performance limits. However, the computational cost associated with high-fidelity simulations demands efficient optimization algorithms. Gradient-based algorithms employing adjoint methods offer the necessary scalability for handling large numbers of design variables. For low Reynolds number regimes ($Re < 10^6$), such as small unmanned aerial vehicles (UAVs) applications, laminar flow may dominate a substantial portion of the wing chord, making the accurate prediction of laminar to turbulent flow transition critical. Conventional turbulence models, such as the Spalart–Allmaras (SA), which assume fully turbulent flow, can lead to misleading design outcomes by either underestimating or overestimating aerodynamic performance. Preliminary studies show that designs optimized under fully turbulent assumptions often fail to maintain their advantages when re-evaluated using laminar-turbulent transition models, and in some cases, exhibit degraded performance. To address this limitation, an algebraic transition model, known as SA-BCM, triggered by a critical empirical momentum-thickness Reynolds number, was integrated into an aerodynamic adjoint-based solver, ADflow in the MACH-Aero framework. This approach enables efficient and robust transition prediction and was implemented to remain compatible with adjoint-based optimization. Validation against experimental data, including cases such as the NACA 0012 airfoil, demonstrated satisfactory agreement. Initial optimization studies incorporating transition modeling yielded improved low-Reynolds-number airfoil designs, with notable gains in aerodynamic efficiency. Beyond enhancing predictive accuracy, the inclusion of transition effects facilitates the design of geometries that favorably manipulate boundary-layer behavior, potentially delaying separation and improving flow control. Ongoing work focuses on extending this capability to three-dimensional configurations, capturing transition phenomena in regions such as wing-fuselage junctions, winglets and propulsion integration. This effort aims to enable a higher fidelity level in aerodynamic shape optimization at low Reynolds number regimes.

Aeroelastic simulation of torsional vibrations in a single-axis solar tracker

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Single-axis solar trackers (SASTs) optimize industrial-scale solar yield by actively pivoting photovoltaic arrays towards the sun. However, their open exposure and lightweight construction make SASTs prone to vibratory instabilities under strong winds, which can lead to structural failure. This investigation presents a cost-effective and agile alternative to aeroelastic wind-tunnel testing for predicting and mitigating extreme torsional vibrations. Wind-induced oscillations in a SAST model are simulated by coupling a structural displacement solver with delayed-detached eddy simulation (DDES) of the turbulent crossflow. The resulting amplitude-frequency response is reported across an operational range of reduced wind velocities at various orientations. Building from validated fluid-elastic modelling practices, this work focuses on predicting the torsional galloping instability (or rotational flutter), as observed in earlier experimental research. The solutions confirm the onset of torsional instability for certain SAST orientations at critical reduced velocities in agreement with peer measurements. Spectral analysis reveals that self-excited vibration is triggered by synchronization between the frequencies of vortex shedding and torsional vibration. Ultimately, the present work demonstrates the numerical fluid-structure interaction (FSI) methodology as a viable approach for the rapid prediction of aeroelastic responses in SASTs. This approach, with its automated parameter control and rapid computational turnaround, significantly streamlines the wind design of open solar structures.

Numerical Modeling of Oceanic Asteroid Impacts Using LSDYNA

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Asteroid impacts have posed a recurring threat throughout Earth's history, with both geological and historical records providing clear evidence of their catastrophic consequences. Given that approximately 70% of Earth's surface is covered by oceans, the probability of an asteroid impacting water is significantly higher than impacting land. In such cases, one of the most hazardous consequences is the generation of impact-induced tsunamis, capable of propagating over vast distances and causing widespread destruction. This study investigates the fluid-structure interaction dynamics of oceanic asteroid impacts using LS-DYNA, an explicit nonlinear finite element solver. A comprehensive sensitivity analysis is performed to evaluate the effects of mesh resolution, time step size, spatial domain extent, and symmetry assumptions—including full 3D, hemispherical, and quarter-sphere representations—on solution stability and accuracy. Numerical convergence and independence are systematically assessed across these parameters. In addition, model validation is carried out through comparison with analytical solutions and established benchmarks in the literature. By refining these simulation strategies, this work advances the modeling of tsunami generation from oceanic impacts and supports improved risk assessment frameworks for planetary defense and coastal hazard mitigation.

Estimating Forest Canopy Fuel Parameters Using a Multi-Source LiDAR Approach for Central Portugal

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Wildfires are a major recurring threat in the Iberian Peninsula, posing severe consequences for ecosystems, biodiversity, and socio-economic systems due to their increasing frequency, intensity, and extent. Crown fires, in particular, are more destructive and difficult to control than surface fires, necessitating accurate modeling of forest canopy fuel characteristics for effective fire management strategies. Four key canopy fuel parameters, canopy height (CH), canopy cover (CC), canopy base height (CBH), and canopy bulk density (CBD), are essential for predicting crown fire behavior. However, these parameters are not readily available at large scales due to the limited availability of airborne LiDAR data. This study addresses this gap by developing and validating a method to estimate and map these canopy attributes in central Portugal using spaceborne GEDI LiDAR data, with support from airborne LiDAR and field data.

The methodology integrates three data sources: GEDI waveforms, airborne laser scanning (ALS) point clouds, and field plot measurements. ALS data were used as reference for CH and CC, while field plots provided calibration for CBH and CBD. Simulated GEDI pseudo-waveforms were generated from ALS point clouds and decomposed using Gaussian modeling to extract vertical structure metrics. These simulations enabled the selection of GEDI Relative Height (RH) metrics best correlated with reference measurements. RH85 showed the strongest correlation with ALS CH ($r = 0.95$; RMSE = 1.81 m), validating its use for CH estimation. Similarly, CC derived from GEDI simulations correlated well with ALS-based CC ($r = 0.87$; RMSE = 0.13). CBH was estimated using a peak separation method from waveform metrics, yielding strong agreement with field data ($r = 0.70$; RMSE = 2.31 m). For CBD, a model integrating waveform-derived structural metrics with field-measured biomass showed moderate accuracy ($r = 0.64$; RMSE = 0.025 kg/m^3).

A key innovation of this study is the direct estimation of fuel parameters from LiDAR data by introducing a new stratification criterion based on Gaussian peak separation and the full width at half maximum (FWHM). Additionally, the use of simulated

GEDI pseudo-waveforms allowed bridging between ALS and GEDI data, enabling parameter estimation in areas without overlapping GEDI and field plots. This approach, combined with canopy structural stratification, proved more effective than classification by forest type alone. Final wall-to-wall maps and associated uncertainty layers were generated for all four fuel parameters, providing valuable spatial inputs for fire risk assessment and ecological modeling across fire-prone Mediterranean landscapes.

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MMP IV: Materials and Manufacturing Processes

Production of thermoplastic composites by pultrusion

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The growth in the use of thermoplastic matrix composite materials presents some challenges in the application of processes already studied with thermosetting matrices.

This paper aims to be a contribution to increase use of thermoplastic matrix composites as alternative to the more traditional thermosetting based composites. First, thermoplastic matrix prepregs were produced in tape form by dipping the fibres into a molten polymer bath. Carbon and glass fibres are used as reinforcement material, testing their combination with thermoplastic polymers and recycled polymers. The use of prepregs is more attractive on the market as the process of mixing and selecting the raw materials is carried out prior to their application in a consolidation process. The prepregs were then processed by pultrusion, which is characterised by its continuous nature, allowing the manufacturing of constant cross section profiles for structural applications.

The pultrusion of thermoplastic composites is still a novelty and therefore presents challenges. The determination of the best combination of operational parameters was also conducted in this study. Finally, the produced profiles were subjected to mechanical tests as a way of assessing the quality of the processed composites. The mechanical properties obtained will be compared to those predicted by the application of micromechanical models using experimentally obtained mass fibre fraction content.

Feasibility research on metal-polymer composite panels with integrated channels for thermal management systems

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In this research work it was assessed the feasibility of employing hybrid friction stir channelling (HFSC) to produce composite panels composed by 8 mm thick AA6082-T651 aluminum alloy and 5 mm glass fibre reinforced Noryl GFN2. HFSC is an innovative solid-state technology that combines both friction stir joining and channelling characteristics that enables the generation of integral internal channels, while joining different components. To this end, a parametric study was outlined to explore the effects of the rotational and travel speeds, as well as probe geometry, length and shoulder clearance on resulting composite panels. Each tool set was composed by a scrolled flat shoulder and one of the two probes designed and manufactured so that both joining and channelling features could be integrated. The resulting composite panels were subsequently subjected to a comprehensive assessment encompassing exterior ceiling quality, internal channel dimensions and surfaces morphology, joining interface morphology, and cross-sectional scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) and micro-hardness profile. Depending on the processing parameters, the geometry of the channels were found to be quasi-rectangular or quasi-trapezoidal with significant variability on cross-sectional area, resulting in hydraulic diameters ranging from 1.2 to 2.9 mm. The joining interface was characterized by a concavity of aluminum that was extruded downwards into the polymeric molten pool that was clinched after polymeric re-solidification. Based on experimental procedures results, joining metals and polymers while creating an integral channel in a single process step is proven to be feasible using HFSC. This way, this fabrication technology evidence promising characteristics that are suitable for manufacturing thermal management systems such as conformal cooling for plastic injection moulding or battery trays for EVs.

Assessment of embedded-element-based models for micro-scale simulation of fibre-reinforced composites

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Composite laminates enable major weight reductions while preserving structural performance, supporting lower fuel consumption and emissions in transport applications. Their structural integrity, however, is tightly linked to microstructure, and service conditions often involve complex loading that can trigger damage and failure. Reliable design therefore benefits from simulation approaches that resolve micro-mechanisms and connect them to macroscopic response.

Aligned discontinuous-fibre (ADF) composites are a promising class for high-performance structures. With highly aligned, high-aspect-ratio fibres, ADF laminates can approach the properties of unidirectional continuous CFRP, yet retain manufacturing advantages. In particular, ADF systems can elongate along the fibre direction when the matrix is molten, enabling forming routes that efficiently produce complex shapes. During forming, fibres remain solid while the polymer matrix softens, creating an anisotropic viscous suspension. The resulting flow and stress transfer depend on microstructural descriptors and understanding how these descriptors affect local fields and global response is crucial to exploit ADF composites in process and structural design.

This work develops micromechanical finite-element models to capture fibre-matrix interactions relevant to forming. Fully resolved models offer detailed insight but become computationally expensive, especially in microstructures with high aspect ratio and volume fraction. To address this, embedded-element strategies are employed in which reinforcing fibres are represented by simplified elements kinematically coupled to the matrix. These formulations bypass fine and conforming meshes, delivering large cost savings.

Finally, an efficient pathway is outlined to obtain the homogenised anisotropic viscosity properties for ADF composites, combined with the validated embedded-element-based FE models. The resulting process-ready parameters provide a practical bridge from microstructure to forming-scale simulations, faithfully reflecting the material’s microstructure descriptors.

Sustainable valorization of wool keratin waste into functional nanofibers via electrospinning using deep eutectic solvents

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Non-renewable resources, particularly those derived from fossil-based materials, remain widely used across various industries. However, growing awareness of their environmental impacts and the depletion of natural resources has emphasized the need for renewable, more sustainable, and environmentally friendly alternatives that align with circular economy principles. Regarding that, valorizing industrial waste, particularly from the textile industry, which is one of the major contributors to global pollution, is a promising approach for developing bio-based materials with functional properties. Particularly, the upcycling of wool keratin (WK), a valuable natural biopolymer extracted from wool waste and a resource that is still often overlooked, has been prominently highlighted. However, traditional methods for WK extraction use toxic and poorly biodegradable compounds, requiring severe chemical treatments that cause environmental issues and compromise the keratin structure, thereby limiting their sustainability. In light of the increasing demand for environmentally friendly solutions, developing green and efficient methods is crucial to promoting sustainable practices in keratin extraction. Deep eutectic solvents (DES) have emerged as a promising alternative to conventional organic solvents due to their low toxicity, biodegradability, and easy preparation. To address this, the present research work explores the use of two different DES composed by Choline Chloride (ChCl) : Urea and L-Cysteine (L-Cys) : Lactic acid (LA), as green alternatives for WK dissolution and regeneration, followed by electrospinning into nanofibers using Nanospider, a needle-free system with a rotating electrode that offers higher productivity and scalability compared to the traditional method. In this context, the WK dissolved in DES was blended with polyvinyl alcohol (PVA) in various ratios to prepare composite nanofibers. The electrospinning solution parameters, including electrical conductivity and viscosity, were then measured to evaluate their influence on the morphology of the electrospun nanofibers. SEM analysis revealed that the blends of PVA and WK dissolved in L-Cys:LA DES exhibited enhanced nanofiber formation compared to WK dissolved in ChCl:Urea DES. Moreover, the electrospun PVA/L-Cys:LA DES-WK nanofibrous materials exhibited remarkable antioxidant and antimicrobial properties.

Hence, combining biopolymers, like WK, with green DES in electrospinning offers a sustainable pathway to valorize wool waste. Moreover, these nanofibrous materials have significant potential in diverse applications and aim to inspire future research toward developing new functional biocomposites with tailored properties by combining WK with other biopolymers.

On the investigation of tailoring local permeabilities of ADFP thin-ply preforms on the enhancement of their VI processability

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This work explores the tailoring of resin flow paths of automated laid preforms during vacuum infusion by investigating the induction of controlled-width gaps and punctures within the preform and checking its permeability. Experimental and numerical analyses of dry tape preforms were conducted, with a particular focus on their permeability. Geometric models of dry tape carbon preforms were modeled based on real preforms' geometric characteristics, exploring imaging and micro-computed tomography. Computational Fluid Dynamics (CFD) simulations were then conducted to predict the permeability of the preforms.

Modular onshore power supply containers made from reused end-of-life wind turbine blades

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There is an increasing emphasis on sustainable practices across industries, with a growing focus on material reuse, recycling, and recovery as sustainable alternatives to conventional disposal methods [1]. For example, it is estimated that global wind turbine blade waste could reach 43 million tons by 2050 [2]. At the same time, European ports are expected to significantly reduce greenhouse gas emissions by 2050 [3]. One potential solution to support this transition is the adoption of electric boats, which requires the development of appropriate supporting infrastructure. Therefore, this research aims to explore the purposeful reuse of end-of-life (EoL) wind turbine blades in the manufacturing of sustainable sandwich panels for modular containers designed for Onshore Power Supply (OPS) systems.

Through a series of mechanical, fire, and physical performance tests, the residual properties of end-of-life (EoL) turbine blades were assessed. Density measurements were conducted in accordance with ASTM C271. Mechanical properties were evaluated using two standardized methods: the three-point flexural test (ASTM C393/C393M) and the edgewise compression test (ASTM C364/C364M). Fire performance was assessed using the single-flame source test (EN ISO 11925-2:2020) and the Single Burning Item (SBI) test, in compliance with EN 13823.

The experimental tests demonstrated good physical and mechanical properties of the EoL turbine blades. Among the tested sandwich panel configurations, the glass laminate with a balsa wood core emerged as the most promising, due to its superior performance compared to the others. However, the EoL turbine blades exhibited poor fire performance. To enhance their fire resistance for use in modular container manufacturing, additional surface treatments, such as fire-retardant paints, fire-resistant intumescent coatings, ceramic/stone-based coatings, fire-retardant resin systems, or mineral-filled barriers, or others, can be applied to the existing surface to improve their fire properties.

The adoption of electric boats is gradually increasing, creating a growing need for a reliable onshore power supply to meet their operational demands. Currently, power supply containers are primarily made of metal, which presents challenges for ports aiming to reduce greenhouse gas emissions. In contrast, the use of lightweight modular containers manufactured with engineered sandwich panels, from EoL turbine blades, offers several advantages, including mechanical strength, durability, and a reduced environmental footprint.

Microstructural and Physical Characterization of Atomet 195 SP Iron Powder for Laser Powder Bed Fusion

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Pure iron has emerged as a promising material for biodegradable medical implants due to its excellent biocompatibility and mechanical strength [1-4]. However, its naturally slow degradation rate and high stiffness pose challenges [1-4]. These can be addressed through additive manufacturing techniques such as Laser Powder Bed Fusion (LPBF), which allow the production of porous and complex structures tailored for biomedical applications [1-4]. This study presents a detailed characterization of Atomet 195 SP water-atomized pure iron powder to assess its suitability for LPBF processing. Scanning electron microscopy (SEM) revealed mostly irregularly shaped particles, with some spherical particles and many smaller satellite particles attached to larger ones—typical of water-atomized powders. Laser diffraction analysis showed a slightly right-skewed particle size distribution, with particle diameters ranging from 15.44 µm (d10) to 53.72 µm (d90), and an average size of 33.89 µm. The tapped density of the powder was measured at 4.00 g/cm3, and the true density was 7.75 g/cm3—close to the theoretical density of pure iron (7.87 g/cm3). Although the powder contained a higher proportion of large particles than expected, the overall characteristics remain within acceptable limits for LPBF. These results support the potential of Atomet 195 SP powder for use in additive manufacturing of biodegradable iron-based implants.

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SMS IV: Structures and Mechanical Systems

How Gear Mesh Stiffness Asymmetry Influences Gear Behaviour

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There are various types of gear mesh stiffness models, including analytical, finite element, hybrid, and approximate models. Each type has its own strengths and weaknesses, making the choice of model dependent on the user's specific requirements. In situations where numerous gear mesh stiffness computations are needed, such as in gear design optimization and gear dynamics, approximate models are often the most suitable option [1]. These models frequently employ approximations of the single tooth pair (slice) mesh stiffness, using parabolic or trigonometric shape functions [2]. However, in most of approximate models, a symmetric shape for the single tooth pair slice mesh stiffness is assumed.

In the work of Marafona et al. [2], an approximate expression for the single tooth pair slice mesh stiffness that accounts for the asymmetric effects is developed. Using the approximate expression [2] together with the gear mesh stiffness modelling framework of Marafona et al. [3], it is possible to, in a fast and accurate manner, evaluate the quasi-static behaviour of spur and helical gears. In addition, through the modelling of a single-stage geared transmission [3], the dynamic behaviour of the gears can also be analysed.

By taking advantage of the previously developed gear mesh stiffness and gear dynamic modelling techniques [3], this research investigates how this stiffness asymmetry influences the gear mesh stiffness, load distribution, and dynamic displacements through a comprehensive simulation analysis. Two sets of 10000 randomly generated gears are tested with and without the asymmetry effect. The results indicate that tooth pair structural stiffness asymmetry has a significant effect on the frequency content of the gear mesh stiffness signal and the dynamic behaviour of the geared system – therefore, it cannot be neglected.

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An analysis of the frequency effect in fatigue data: from uniaxial to multiaxial loading

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In recent years, very high cycle fatigue (VHCF) has attracted significant interest, primarily due to sustainability goals aimed at extending the service lives of engineering components and structures. This regime's assessment requires higher testing frequencies to reduce the time needed to achieve the region beyond 10 million cycles [1]. As a result, ultrasonic fatigue testing became a commercial testing system with a wide range of applications since the high frequency of testing (around 20 kHz) allows for a substantial reduction in the testing time or even the feasibility of evaluating certain fatigue lives.

However, as stated by several authors [2], [3], the fatigue behaviour can be affected by the frequency of testing, which leads to dissimilar experimental data for the same material, depending on the testing technology. Additionally, the sensitivity of materials to the frequency effect can be diverse and challenging to predict or comprehend. As a result, the applicability of ultrasonic fatigue data may be significantly compromised.

Therefore, this work analyzes the frequency effect in different metallic materials, considering uniaxial and multiaxial loading scenarios, to comprehend its leading causes. For example, aluminium alloys with an fcc (face-centred cubic) crystal structure tend to present a negligible frequency effect, since the stress required to move a dislocation is considerably low. On the other hand, alloys with bcc (body-centred cubic) crystal structure, such as mild steels, demonstrate high sensitivity to the frequency effect [4]. Furthermore, this work will also address the modelling of this effect considering probabilistic analysis.

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Modified gears for constant mesh stiffness

Pedro Marques
FEUP

Gear mesh stiffness (GMS) fluctuations are one of the main drivers of dynamic excitation of a gear system, promoting an oscillating load between gear teeth. A perfectly manufactured and assembled constant mesh stiffness gear (CMS gear) can be defined as the gear that eliminates gear mesh stiffness fluctuations.

This work proposed a conceptual method to eliminate gear mesh stiffness (GMS) fluctuations in spur and helical gears. This was achieved by prescribing a flank line crowning that varies along the gear's path of contact. Traditional profile and flank modifications reduce dynamic excitation but cannot fully eliminate GMS variations, which contribute to transmission error, vibration, and noise. Here, a new design principle is proposed: shape the single tooth mesh stiffness (STMS) to match the gear's load sharing (LS) shape, thus achieving constant GMS under ideal conditions. Assuming a constant output torque, the sum of the tooth load sharing (LS) functions for all the tooth pair in mesh at a single instant must always be equal to a constant value, which is a fundamental property of the shape of the functions that describe the LS behavior for single tooth pairs in mesh along the plane of action. This is the reason for matching the shapes of the LS and STMS.

An analytical, non-iterative model was also developed to calculate LS for spur and helical gears with flank line crowning using elliptical Hertzian contact theory while assuming gear teeth modeled as barrel-shaped bodies. This additional development was key in determining a variable crowning profile along the path of contact that yields a contact stiffness which, when combined with the structural and foundation stiffness, produces a constant total mesh stiffness.

The behaviour of a gear modified according to the proposed approach considering operation out of the design load and imperfections was also evaluated. The results showed that the GMS was not constant anymore, expectedly, but the fluctuations were still much lower than the reference results for the unmodified gear.

The proposed method provides a viable theoretical basis for gear design targeting constant mesh stiffness through variable flank line crowning. Though manufacturing complexity and load sensitivity remain challenges, this approach offers a novel framework for optimizing gear performance via controlled stiffness shaping.

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Identifying the most appropriate lifetime variable for maintenance freight wagon wheelsets

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Railway freight transit provides an optimal alternative for moving substantial goods across various distances, reducing road congestion and environmental impact. Efficient railway transportation necessitates appropriate maintenance; wheelset maintenance is crucial for freight vehicles to ensure safety and cost-effectiveness. Insufficient efforts have been undertaken to improve the maintenance of freight wagons. This research article identifies the most suitable lifetime variable for freight wagon wheelsets, compared to time, mileage, and gross ton mileage since maintenance. This comparative study employs regression analysis to model wear trajectories, survival analysis for damage trajectories, and reinforcement learning for choice policy analysis of the degradation rates of wheelsets from passenger coaches versus goods wagons. The findings underscore the essential significance of gross ton mileage in predictive maintenance, providing practical insights to improve decision-making and decrease expenses while enhancing the reliability and safety of compromised assets.

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Investigating Gear Mesh Stiffness in High Contact Ratio Plastic Gears

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Gears are fundamental mechanical components, playing a critical role in power transmission and motion control across an extensive range of applications, from micro-scale precision instruments to large-scale industrial machinery and aerospace systems. In recent decades, there has been a significant increase in the adoption of plastic gears, primarily due to their advantageous properties such as lower weight, reduced noise, self-lubrication capabilities, and cost-effective manufacturing [1]. However, a notable characteristic of plastic gears is their susceptibility to severe elastic deformations under load. These deformations can drastically increase the instantaneous contact ratio, often leading to values significantly greater than 2, implying that more than two pairs of teeth are simultaneously in contact.

Gear mesh stiffness is a pivotal parameter that profoundly influences the load distribution among engaging teeth and dictates the dynamic behaviour of the entire gear system. Accurate determination of mesh stiffness is therefore crucial for predicting performance and optimizing design. Previous research has established the existence of a coupling effect between successive teeth in terms of their contribution to overall mesh stiffness. In particular, Xie et al. [2] developed an analytical model that includes the structure coupling effect between successive teeth within the gear body deflections. This study aims to extend that foundational work to account for contact ratios greater than 2, a scenario frequently encountered in highly deformable plastic gear applications.

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Toward modeling transfer film evolution in tribological contacts: A preliminary computational approach

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Friction and wear in sliding contacts are strongly influenced by the presence of third bodies---material fragments or films that form and evolve between contacting surfaces. These third bodies mediate the interaction between the main surfaces, often altering the local contact conditions and controlling the tribological response. A prominent example is the transfer film, a thin layer that develops during sliding, particularly in polymer-metal interfaces [1]. This film can significantly reduce friction and wear by modifying the near-surface mechanical and chemical environment. In self-lubricating systems, the formation of transfer films is critical to ensuring efficient and durable performance, even under extreme conditions such as high loads or temperatures [2]. However, the mechanisms driving transfer film formation, such as adhesion, material detachment, and redistribution, are complex and remain insufficiently understood.

This work presents a preliminary numerical framework for modelling transfer film formation as a third-body process in polymer sliding contacts. The approach relies on a dual-mortar method for contact discretisation [3], enabling a robust representation of friction and contact constraints. Relying on simple phenomenological modelling approaches based on Godet's concept of third body [4], an explicit wear algorithm [5] is developed to account for material loss and film growth during sliding. Numerical examples validate the model by analysing how the inclusion of transfer film dynamics affects the wear and friction response in polymer-metal contacts. A key finding is that the presence of transfer films can significantly alter the tribological behaviour, leading to reduced friction and wear volume, when compared to scenarios without film formation. The findings emphasise the importance of accurately modelling transfer film formation to enhance the design of self-lubricating systems.

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BIO III: Biomechanics

Association between Maximum Handgrip Strength and Force-Time Curve Indicators from Handgrip Digital Dynamometry with Undernutrition Risk in a Multicentre Cross-Sectional Sample of Heart Failure Outpatients - The NUTRIC Project

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Introduction. Undernutrition is highly prevalent in patients with heart failure (HF) and is associated with worse prognosis. While maximum handgrip strength (mHGS) is a simple and widely used indicator, emerging metrics derived from handgrip force-time curves may offer improved assessment.

Objective. To compare the association of mHGS and force-time curve indicators with undernutrition risk in ambulatory HF patients.

Methods. This multicentre cross-sectional study is part of the NUTRIC – Nutrition and Functional Status in Heart Failure – Project, and included outpatients from three Portuguese public hospitals. HGS data was assessed using an innovative digital wireless dynamometer (GripWise®), enabling the extraction of detailed force-time curve information. The following measures were computed: mHGS, total area under the force-time curve (AUC), pre-peak AUC, and post-peak AUC. Undernutrition risk was assessed using the Malnutrition Universal Screening Tool for participants <65 years and the Mini-Nutritional Assessment - Short Form® for those ≥65 years. Sociodemographic, clinical, and anthropometric data were also collected. Participants were stratified into sex-specific tertiles for mHGS and each force-time curve indicator, with tertile 1 representing the lowest strength and tertile 3 the highest. Logistic regression models were used to estimate odds ratios (OR) with 95% confidence intervals (CI), adjusted for sex, New York Heart Association functional class, and left ventricular ejection fraction.

Results. A total of 207 HF outpatients (44.4% women; 71±12.5 years old) were included, with 35.7% classified as being at medium or high risk of undernutrition. Mean left-hand mHGS was 23.7±8.0 kgf for men and 13.3±12.9 kgf for women ($p<0.001$). For left-hand mHGS, participants in the second tertile had lower odds

of undernutrition risk (OR=0.40; 95%CI: 0.19-0.88; p=0.021), with a stronger association in the third tertile (OR=0.29; 95%CI: 0.13-0.65; p=0.003). For left-hand total AUC, both the second (OR=0.30; 95%CI: 0.13-0.69; p=0.005) and third tertiles (OR=0.30; 95%CI: 0.13-0.70; p=0.005) showed similarly reduced odds. Total AUC demonstrated a more consistent association across intermediate and high tertiles than mHGS.

Conclusion. Both mHGS and total AUC are independently associated with undernutrition risk in HF outpatients. These findings suggest that digital dynamometers may enhance undernutrition assessment by capturing early strength deficits through force-time profiles, offering added value beyond conventional mHGS measures.

Modeling the Dynamics of Vacuum-Assisted Delivery: A Biomechanical Study

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Vacuum-assisted delivery (VAD) is a widely used intervention to facilitate childbirth. In Portugal, instrumental deliveries accounted for 20% of vaginal births in the past 12 months. Despite its common occurrence, VAD raises apprehensions regarding maternal pelvic floor dysfunction [1]. Obstetricians still have some uncertainties about the ideal duration of vacuum delivery, the impact of contraction duration and resting stages, and the ideal number of pulls. This highlights the need for extensive studies to elucidate the biomechanics of this procedure [2]. The main goal of this study is to biomechanically analyze the impact of VAD on maternal tissues.

A finite element model of the pelvic floor muscles, perineal structures, and fetal head was used to simulate VAD. A Kiwi Omnicup Vacuum Device, with a diameter of 60 mm and a height of 20 mm, was included. Childbirth simulations were performed in Abaqus® software with the fetus in a vertex presentation and occipito-anterior position. A total of twelve simulations of VAD were performed according to clinical scenarios. The parameters varied were the contraction duration, the resting periods between contractions, and the total number of pulls required to extract the fetus. During the simulations, the Augmented Lagrange contact method was used to model the interactions between the PFM, perineum, and fetal head. A tie constraint was applied between the fetal head and the vacuum cup. The movements of the vacuum cup were controlled by a reference node, which defined its descent and rotation.

Results demonstrated that shorter contraction and resting times resulted in higher stress values, with a maximum stress of 0.782 MPa. Additionally, extracting the fetus with only two pulls leads to higher stress on the muscles compared to three or four pulls. Fetal extraction performed with two pulls also demands a higher force than the other scenarios.

This study examines the biomechanics of VAD, with particular emphasis on factors that may play a crucial role in preventing pelvic floor injuries. From a mechanical standpoint, prioritizing maternal health, longer contraction durations paired with extended rest periods are beneficial for maternal muscles. Additionally, obstetricians should aim to minimize excessive force during individual pulls. The findings offer valuable knowledge on the biomechanics of assisted delivery, emphasizing the importance of optimizing techniques to minimize maternal trauma.

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Diagnosis, Monitoring, and Functional Recovery of Knee Musculoskeletal Injuries

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The recovery process after knee prosthesis implantation is critical for restoring mobility and ensuring long-term patient outcomes. However, current clinical practise still relies on observational and qualitative methods, which cannot provide continuous or quantitative information regarding the patient's functional progress. This limitation the detection of complications, the adjustment of rehabilitation strategies, and reduces patients' active involvement in their recovery.

To address these challenges, MyKneeRecovery was developed, a wearable system integrated with a mobile application designed to provide real-time, objective, and patient-centred monitoring during post-surgical knee rehabilitation.

The wearable device incorporates inertial measurement units (IMUs), temperature sensors, and step-counting functionality, enabling the acquisition of biomechanical and physiological parameters that are clinically relevant. The system measures knee range of motion, number of flexion/extension movements, joint temperature, and step counts per hour. All data are transmitted to a mobile application that allows patients to visualise their own progress, while clinicians gain remote access to recovery trajectories, supporting more informed decision-making.

Beyond monitoring, MyKneeRecovery is being enhanced with predictive algorithms to estimate the percentage of functional recovery throughout the rehabilitation process. By combining sensor-derived features with demographic and clinical information, the algorithms aim to generate personalised recovery plans, enabling early identification of deviations from expected trajectories. This approach promotes a more precise adjustment of rehabilitation protocols and facilitates the design of individualised treatment strategies.

The system represents a portable, cost-effective, and clinically relevant alternative to traditional motion capture technologies, which are often expensive, complex, and impractical for routine clinical use. By combining subjective assessments with quantitative, real-time data, MyKneeRecovery contributes to improved rehabilitation outcomes, enhanced patient engagement, and the broader adoption of digital health solutions in orthopaedics.

Identifying Human Factors in Aviation Accidents with Natural Language Processing and Machine Learning Models

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The application of machine learning (ML) techniques to the identification of factors that contribute to air incidents has seen substantial growth over the years. ML enhances early detection and accident prevention, while strengthening operational safety in aviation. In this study, classification models, namely Least Squares (LS), K-Nearest Neighbors (KNN), Random Forest, Extra Trees, and XGBoost – all widely recognized for their effectiveness in classification tasks – are employed to analyze incident reports processed through natural language processing (NLP) techniques, with the objective of uncovering latent patterns and mitigating future occurrences. The performance of the predictive models is assessed using metrics such as precision, recall, F1-score, and accuracy. Hyperparameter optimization is carried out via Grid Search and Bayesian Optimization. Among the evaluated models, KNN achieved the highest predictive performance, followed by Random Forest and Extra Trees. The findings demonstrate that the use of machine learning tools for incident and accident classification is an effective approach to identifying root causes, thereby supporting more informed situational decision-making.

Immersive Tools for The Future of Mining Engineering Students

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The extractive industry is one of the fundamental industries that drives world industrial growth. It is the pillar supporting several other industries, such as civil construction, automobiles, and aviation, by providing them with essential raw materials. In 2025, the demand and use of mineral resources will continue to increase at a rapid rate, driven by increased urbanization, infrastructure expansion, and population growth across the world. This forces the mining industry to extract more resources while coping with mounting environmental and safety problems.

Mining operations, particularly open-pit and underground mining, are dynamic and intricate in nature. The workplace undergoes constant change with the advancement of exploitation, rendering it difficult to represent and understand the operations as a whole, using traditional teaching approaches. Besides, mining remains one of the world's most hazardous industries with significant risks entailed in geotechnical failure, equipment operation, and the environment.

In addition, one of the serious concerns for the industry is the phenomenon of declining student interest and enrolment in Mining Engineering programs. This trend has mostly been accounted for by the shortcomings of conventional classroom pedagogical techniques, which are mostly found not to capture the attention of students to cope with the intricacies and magnitude of mining operations in the field. Therefore, enhancing students' motivation and their understanding of processes involved in mining has become a necessity for educational institutions.

This work proposes the use of immersive tools, such as Serious Games and Virtual Reality (VR), as innovative learning tools to bridge the gap between theory and practice while complying with the Sustainable Development Goals. Under the scope of the "HoloGEM" project, a VR-based simulation of an exploitation was developed for Mining Engineering education. The simulation replicates a real-life open-pit mine environment and includes advanced modelling of the open-pit geometry, machinery used, and the entire exploitation process, from initial planning and drilling to extraction and haulage.

The development of the simulation utilized a combination of advanced digital tools, including Unity for creating the game engine, Blender for three-dimensional modelling, and Peel3D for real-world object scanning. These tools allowed for the execution of extremely detailed and interactive mining environments where students are able to explore and learn in a risk-free scenario.

The simulation will be piloted and tested in collaboration with Mining Engineering students from different European countries, including Turkey, Poland, and Portugal. Feedback will be collected to identify the effectiveness of the tool in improving student interaction, understanding of complex mining operations, and overall learning.