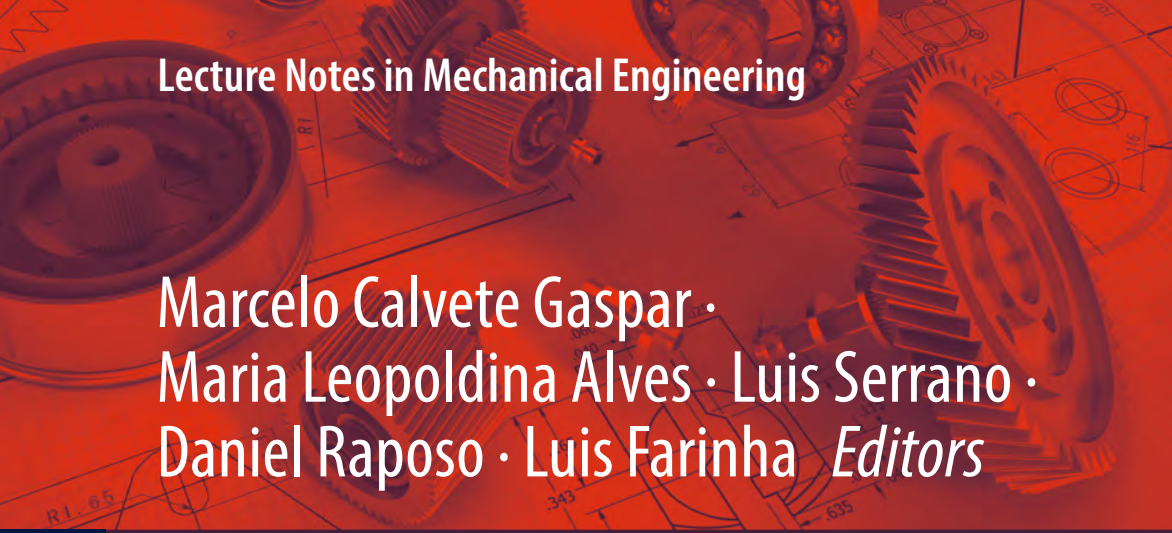




Lecture Notes in Mechanical Engineering

Marcelo Calvete Gaspar ·
Maria Leopoldina Alves · Luis Serrano ·
Daniel Raposo · Luis Farinha *Editors*

Sustainable Innovations in Mechanical Engineering

Selected Contributions to the
8th International Conference
on Sustainable Innovation,
Entrepreneurship and Technology
(RegionalHelix 2024), November
14–16, 2024, Leiria, Portugal

Lecture Notes in Mechanical Engineering

Series Editors

Fakher Chaari, *National School of Engineers, University of Sfax, Sfax, Tunisia*

Francesco Gherardini , *Dipartimento di Ingegneria “Enzo Ferrari”, Università di Modena e Reggio Emilia, Modena, Italy*

Vitalii Ivanov , *Department of Manufacturing Engineering, Machines and Tools, Sumy State University, Sumy, Ukraine*

Mohamed Haddar, *National School of Engineers of Sfax (ENIS), Sfax, Tunisia*

Loon Ching Tang, *Department of Industrial Systems Engineering and Management, National University of Singapore, Singapore, Singapore*

Editorial Board Members

Francisco Cavas-Martínez , *Departamento de Estructuras, Construcción y Expresión Gráfica Universidad Politécnica de Cartagena, Cartagena, Spain*

Francesca di Mare , *Institute of Energy Technology, Ruhr-Universität Bochum, Bochum, Germany*

Young W. Kwon, *Department of Manufacturing Engineering and Aerospace Engineering, Graduate School of Engineering and Applied Science, Monterey, USA*

Tullio A. M. Tolio, *Department of Mechanical Engineering, Politecnico di Milano, Milano, Italy*

Justyna Trojanowska, *Poznan University of Technology, Poznan, Poland*

Robert Schmitt, *RWTH Aachen University, Aachen, Germany*

Jinyang Xu, *Faculty of Intelligence Technology, Shanghai Institute of Technology, Shanghai, China*

Lecture Notes in Mechanical Engineering (LNME) publishes the latest developments in Mechanical Engineering—quickly, informally and with high quality. Original research or contributions reported in proceedings and post-proceedings represents the core of LNME. Volumes published in LNME embrace all aspects, subfields and new challenges of mechanical engineering.

To submit a proposal or request further information, please contact the Springer Editor of your location:

Europe, USA, Africa: Leontina Di Cecco at Leontina.dicecco@springer.com

China: Ella Zhang at ella.zhang@cn.springernature.com

India, Rest of Asia, Australia, New Zealand: Swati Meherishi at swati.meherishi@springer.com

Topics in the series include:

- Engineering Design
- Machinery and Machine Elements
- Mechanical Structures and Stress Analysis
- Automotive Engineering
- Engine Technology
- Aerospace Technology and Astronautics
- Nanotechnology and Microengineering
- Control, Robotics, Mechatronics
- MEMS
- Theoretical and Applied Mechanics
- Dynamical Systems, Control
- Fluid Mechanics
- Engineering Thermodynamics, Heat and Mass Transfer
- Manufacturing Engineering and Smart Manufacturing
- Precision Engineering, Instrumentation, Measurement
- Materials Engineering
- Tribology and Surface Technology

Indexed by SCOPUS, EI Compendex, and INSPEC.

All books published in the series are evaluated by Web of Science for the Conference Proceedings Citation Index (CPCI).

To submit a proposal for a monograph, please check our Springer Tracts in Mechanical Engineering at <https://link.springer.com/bookseries/11693>.

Marcelo Calvete Gaspar ·
Maria Leopoldina Alves · Luis Serrano ·
Daniel Raposo · Luis Farinha
Editors

Sustainable Innovations in Mechanical Engineering

Selected Contributions to the 8th International
Conference on Sustainable Innovation,
Entrepreneurship and Technology (RegionalHelix
2024), November 14–16, 2024, Leiria, Portugal

Editors

Marcelo Calvete Gaspar 
Instituto Politécnico de Leiria
Leiria, Portugal

Maria Leopoldina Alves 
Instituto Politécnico de Leiria
Leiria, Portugal

Luis Serrano 
Instituto Politécnico de Leiria
Leiria, Portugal

Daniel Raposo 
Instituto Politécnico de Castelo Branco
Castelo Branco, Portugal

Luis Farinha 
Instituto Politécnico de Castelo Branco
Castelo Branco, Portugal

ISSN 2195-4356

ISSN 2195-4364 (electronic)

Lecture Notes in Mechanical Engineering

ISBN 978-3-032-36364-0

ISBN 978-3-032-36365-7 (eBook)

<https://doi.org/10.1007/978-3-032-36365-7>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2027

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Unless otherwise expressly agreed by the Publisher in writing, the Publisher does not authorize use or reproduction of all or any part of this work in any manner for the purpose of training, fine-tuning, evaluating, or developing artificial intelligence models, technologies, or systems. In accordance with Article 4(3) of the EU Directive 2019/790 on copyright and related rights in the Digital Single Market, the Publisher expressly reserves all rights with respect to this work under the text and data mining exception of the directive.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

If disposing of this product, please recycle the paper.

Preface

This volume of the Lecture Notes in Mechanical Engineering (LNME) presents peer-reviewed contributions within the Regional Helix framework under the theme of Sustainable Innovation in Mechanical Engineering. The chapters collectively articulate contemporary mechanical engineering applied research that reshape design, production and mobility systems to innovate through and within sustainability guidelines. Beyond presenting incremental advances through sustainability-oriented innovation, the chapters emphasize maintenance and reparability case studies, life-extension of assets, resource and energy efficiency in processes, interoperability across cyber-physical production systems, and data-informed decision-making at component, process, and system levels.

The Regional Helix framework is intentionally multidisciplinary and application-oriented while integrating academic, industrial, and public-sector perspectives. This integration is reflected in the contributions, which balance methodological development with application in applied operational contexts. The resultant body of work illustrates a consistent concern for measurability, replicability, and the translatability of findings into engineering practice, thus helping researchers, students and practitioners to implement more sustainability-oriented strategies and solutions.

The organizers received 29 contributions for this volume. After a thorough peer-review process (double-blind review), the committee accepted 20 papers, with an acceptance rate 69%. At least three independent reviewers evaluated each paper. To evaluate each paper, reviewers were asked to answer, among others, questions about the originality of the paper, the significance of presented results, comprehensibility, scientific merit and relevance for the Regional Helix framework. All submitted papers were checked for similarity using Turnitin.

This volume is organized into four technical subsections that range from the implementation of sustainable and innovative technologies and solutions to system-level sustainability outcomes: (I) Advanced Manufacturing and Digital Systems; (II) Maintenance and Asset Management; (III) Energy and Environment; and (IV) Sustainable Mobility and Transportation.

The first part entitled Advanced Manufacturing and Digital Systems assembles contributions on robotics-enabled additive manufacturing (AM), digital readiness, and interoperability as foundational enablers of sustainable production. The section encompasses a state-of-the-art review of robot-assisted AM platforms and control architectures; a bibliometric analysis of digital-maturity assessment models relevant to Industry 4.0 transitions; and an interoperability case using OPC UA within injection-moulding environments to enable traceability, efficient data exchange, and energy-aware operation. A case study on polymer injection moulds highlights and discusses welding-based reconditioning strategies. Together these studies evidence how advanced manufacturing and data infrastructures shorten the path from concept to circular products.

The second part dedicated to Maintenance and Asset Management focuses on sustaining performance through predictive, standardized, and decision-intelligent approaches.

Methodological contributions include a proportional hazards (Cox) modelling framework for predictive maintenance in Industry 5.0 settings and a decision-support architecture that formalizes multi-criteria evaluation for complex industrial systems. Alongside these, dedicated case studies show how disciplined improvement translates directly into uptime and quality. This section shows that sustainability-oriented strategies allow for extend asset life, improved maintenance policies, and reduced environmental impacts related with waste and premature replacements.

The third part focusing on Energy and Environment addresses process-scale resource performance and environmental impact mitigation. Contributions include energy-aware control of suspended-load movement, thermal optimization of pellet boilers, and two materials-processing studies that are related to circular value chains: the valorization of limestone-quarry waste into precipitated calcium carbonate and a model for separating plastics by dissolution/precipitation. These studies pair modelling with empirical validation, evidencing quantifiable gains in energy efficiency, material recovery, and substitution potential, while preserving or enhancing functional performance.

The fourth part dedicated to Sustainable Mobility and Transportation considers the design and operation of mobility systems with attention to performance metrics and environmental accounting. The section includes ride-comfort analytics for electric scooters aligned with ISO 2631, a genetic-algorithm framework for the optimization of vehicle suspension parameters, fleet-level CO₂ assessment tools for heavy-duty vehicles, and analyses of maintenance-related environmental impacts under biofuel operation. A complementary case study on aircraft landing-gear trends rounds out the set. The section demonstrates that sustainable mobility outcomes emerge from the interaction of component design, control strategies, operational practices, and robust measurement infrastructures.

Three transversal trends run through the volume. First, circularity is being operationalized: from welding-based repair and reconditioning of tooling to the upcycling of Nylon-6 fishing nets via large-scale additive manufacturing and micro-factories, the papers illustrate how product life-extension and local production can be engineered as systematic capabilities rather than one-off projects. Second, digitalization is maturing beyond pilots: interoperability standards, digital-maturity assessment and asset-intelligence methods are being applied to create trustworthy data flows that support optimization across the life cycle. Third, measurement is becoming integral to design and management decisions, thus closing the loop between targets, interventions and outcomes.

The contributions further indicate that environmental and economic objectives can be jointly satisfied when interventions are formulated as engineering optimizations subject to operational constraints. Interoperable control reduces information latency and improves utilization; predictive maintenance extends asset life and mitigates unplanned losses; process-level energy optimization lowers operating costs while reducing emissions; and transport analytics provide a basis for accountable decarbonization trajectories. In aggregate, the studies offer a transferable set of methods that organizations may adopt incrementally with cumulative effect.

The editors extend their appreciation to all authors for entrusting us with their work and for engaging constructively with the review process. We are equally indebted to the

anonymous reviewers and track organizers for their time, expertise and careful assessments and to the Regional Helix organizing committee for the platform that enabled these exchanges. We acknowledge our institutions and partners for their support throughout the editorial process and extend our appreciation to the Springer LNME team for guidance during production.

We hope this collection serves researchers, students and practitioners as a practical reference for designing mechanical systems that are efficient, repairable and resilient. The editors trust that the ideas and tools presented here will inform future research projects, industrial deployments and curricula devoted to sustainable innovation in mechanical engineering.

Leiria, Portugal

Marcelo Calvete Gaspar
Maria Leopoldina Alves
Luis Serrano
Daniel Raposo
Luis Farinha

Organization

Chairs

Marcelo Gaspar	Polytechnic Institute of Leiria
Maria Leopoldina Alves	Polytechnic Institute of Leiria
Luís Serrano	Polytechnic Institute of Leiria
Daniel Raposo	Polytechnic Institute of Castelo Branco
Luís Farinha	Polytechnic Institute of Castelo Branco

Scientific Committee

Aidin Salamzadeh	University of Tehran
Alexandre Guedes	University of Trás-os-Montes and Alto Douro
Ana Rodrigues	University of Trás-os-Montes and Alto Douro
Ana Melo	CIPES/ESTGA—University of Aveiro
Ana Claudia Machado Padilha	University of Passo Fundo
Ana Patricia Vilha	UFABC—Federal University of ABC
Anderson Galvão	CETRAD and University of Trás-os-Montes and Alto Douro
Arminda Paço	NECE and University of Beira Interior
Artur Pires	University of Aveiro
Beatriz Casais	University of Minho
Benjamim Fonseca	University of Trás-os-Montes and Alto Douro
Carina Silva	CIICESI, School of Technology and Management, Polytechnic Institute of Porto
Carla Mascarenhas	University of Beira Interior
Carla S. Marques	CETRAD and University of Trás-os-Montes and Alto Douro
Carlos Marques	CETRAD and University of Trás-os-Montes and Alto Douro
Carlos Rodrigues	University of Aveiro
Carlos Sampaio	Polytechnic Institute of Castelo Branco
Carmem Leal	CETRAD and University of Trás-os-Montes and Alto Douro
Cristina Fernandes	FEP—School of Economics and Management of the University of Porto

Daniel Raposo	Polytechnic Institute of Castelo Branco
David Rodeiro Pazos	University of Santiago de Compostela
Elisabete Figueiredo	University of Aveiro
Fernando Ferreira	BRU and ISCTE/University Institute of Lisbon
Helena Alves	University of Beira Interior
Joana Lima	University of Évora
João Ferreira	NECE and University of Beira Interior
João Neves	Polytechnic Institute of Castelo Branco
João Nuno Lopes	CETRAD and Lusófona University
João Renato Sebastião	Polytechnic Institute of Castelo Branco
Jorge Remondes	ISVOUGA, Higher Institute of Entre Douro and Vouga
Jorge Cunha	University of Minho
Jorge Julião	Catholic University of Portugal
José Machado	University of Minho
Jose Manuel Hernandez Mogollón	University of Extremadura
Liliana Alves	University of Aveiro
Liliana Neves	Polytechnic Institute of Castelo Branco
Luís Farinha	NECE and Polytechnic Institute of Castelo Branco
Luís Serrano	Polytechnic Institute of Leiria
Marcelo Gaspar	Polytechnic Institute of Leiria
Márcio Jacometti	Federal University of Technology, Paraná
Marcus Dejardin	University of Namur/Catholic University of Louvain
Maria José Rainho	UTAD—University of Trás-os-Montes and Alto Douro
Maria Leopoldina Alves	Polytechnic Institute of Leiria
Marina Ranga	University of Warsaw
Marisa Ferreira	CIICESI, School of Technology and Management, Polytechnic Institute of Porto
Mete Basar Baypinar	University of Istanbul
Octávio Sacramento	UTAD—University of Trás-os-Montes and Alto Douro
Orlando Rua	Polytechnic Institute of Porto—ISCAP
Paula Odete Fernandes	UNIAG, Polytechnic Institute of Bragança
Paulo Mourão	University of Minho
Pedro Torres	Polytechnic Institute of Castelo Branco
Ricardo Bento	UTAD—University of Trás-os-Montes and Alto Douro
Ricardo G. Rodrigues	NECE and University of Beira Interior
Rui Silva	CETRAD and University of Trás-os-Montes and Alto Douro

Rui Patrício	IADE—Faculty of Design, Technology and Communication
Sérgio Teixeira	ISAL—Higher Institute of Administration and Languages
Teresa Felgueira	Polytechnic Institute of Guarda
Teresa Paiva	Polytechnic Institute of Guarda
Tomaz Dentinho	University of the Azores
Vanda Lima	CIICESI, School of Technology and Management, Polytechnic Institute of Porto
Vitor Braga	CIICESI, School of Technology and Management, Polytechnic Institute of Porto

Section Contributors

Armando Ramalho	Polytechnic Institute of Castelo Branco
Carlos Catorze Pereira	Polytechnic Institute of Viseu
Carlos Neves	Polytechnic Institute of Leiria
Daniel Gaspar	Polytechnic Institute of Viseu
Helder Santos	Polytechnic Institute of Leiria
Henrique Almeida	Polytechnic Institute of Leiria
Jorge Siopa	Polytechnic Institute of Leiria
Jorge Julião	Católica Porto Business School
Luís Coelho	Polytechnic Institute of Leiria
Mário Correia	Polytechnic Institute of Leiria
Milena Vieira	Polytechnic Institute of Leiria
Olivier Gouveia	Polytechnic Institute of Leiria
Paulo Carvalho	Polytechnic Institute of Leiria
Pedro Custódio	Polytechnic Institute of Leiria
Rui Rúben	Polytechnic Institute of Leiria
Silvia Monteiro	Polytechnic Institute of Leiria

Contents

Advanced Manufacturing and Digital Systems

A Review on Robot-Assisted Additive Manufacturing Systems and Technologies	3
<i>Marcella Cavalcanti, Hugo Costelha, and Carlos Neves</i>	
Twin Transitioning to Local Circular Production Systems: Upcycling Fishing Nets through Large-Scale Additive Manufacturing and Microfactories	14
<i>Robin Teigland, Mohammad Rouhi, Woodrow Wiest, Markus Eriksson, Jon Erik Borgen, and Karoline Teigland</i>	
Bibliometric Analysis of Digital Maturity Assessment Models for Industry 4.0	30
<i>G. G. M. P. da Silva, A. Guimarães, Marisa G. Pereira, F. A. Ferreira, and M. T. Pereira</i>	
Industry 4.0 & Sustainability: A Case Study of OPC UA Injection Moulding Machine	48
<i>A. Kaduk, L. Ferreira, and C. Neves</i>	
Welding Processes on AISI H11, P20 and 420 Tool Steels for Polymer Injection Molds	60
<i>J. P. Rasteiro, A. A. Nogueira, M. M. Vieira, and M. A. Correia</i>	

Maintenance and Asset Management

Asset Management and the Digital Transformation of Companies in Portugal: A Thematic Literature Review	75
<i>André Guimarães, Samuel Messias, Hugo Raposo, and Daniel Gaspar</i>	
Challenges and Opportunities for the Industry in Implementing Circular Economy Through Repair—Insights from the European Union Legislation	90
<i>Berta Costa, Susana Rodrigues, Susana Almeida, and Jacob C. Bazen</i>	
Proportional Cox Model and Its Potential Application to Predictive Maintenance in Industry 5.0	111
<i>Jorge Siopa, Pedro Custódio, Joana F. A. Valente, João Marcelino, Diogo Montalvão, and João Pombo</i>	

Implementing SMED in the Tool Change of Glass Inspection Machines: A Case Study	125
<i>Marcelo Cardoso, M. L. Alves, and M. Jacometti</i>	
The Integration of Digital Transformation in Asset Management in Portuguese Companies	136
<i>Samuel Messias, André Guimarães, Hugo Raposo, and Daniel Gaspar</i>	
Enhancing G-SIB Evaluation with the PSI-WISP Method: A Proposed Framework	152
<i>Felipe Fortuna Lucas, Carlos Francisco Simões Gomes, Marcos dos Santos, Solange Maria Fortuna Lucas, Fernanda Amélia Ferreira, and Maria Teresa Pereira</i>	
Energy and Environment	
Efficiency and Energy Consumption in Suspended Load Movement Control ...	173
<i>Diogo Baptista and Carlos Neves</i>	
Optimization of the Thermal Efficiency of a Domestic Pellet Boiler	188
<i>Daniel Gouveia, Tânia Ferreira, and Carlos Pereira</i>	
Valorisation of Limestone Quarry Waste for a Local Sustainable Precipitated Calcium Carbonate Production	201
<i>N. S. Oliveira, S. Monteiro, M. L. Heleno, M. L. Alves, A. Veiga, and A. Silva</i>	
Model Proposal for Separation of Plastics by Dissolution/Precipitation Process	213
<i>Lizete Heleno, Joel Correia Vasco, Nelson Simões Oliveira, Marcelo Gaspar, and Ana Silveira</i>	
Sustainable Mobility and Transportation	
Smart and Cost-Effective System for Monitoring Electric Scooter Comfort Based on ISO 2631 Vibration Standards	233
<i>Hélio Mendonça, Armando L. Ramalho, Pedro M. B. Torres, and Volker Lohweg</i>	
Analysis of the Environmental Impacts Caused by Required Adjustments in Heavy-Duty Vehicles Maintenance Related to Biodiesel Consumption	247
<i>Carlos Jacinto, Bruno Rodrigues, Diogo Silva, Ricardo Almeida, Fonseca Pereira, and Luis Serrano</i>	

Implementation of CO ₂ Emissions Assessment System in Heavy-Duty Vehicles in Portugal	262
<i>Duarte Vieira, Paulo Carvalho, Ricardo Almeida, Diogo Silva, and Luis Serrano</i>	
Development of an Optimization Framework for Suspension Parameters in Automotive Vehicles Using Genetic Algorithms	277
<i>Iúri Silva, Fernando Batista, and Olivier R. Gouveia</i>	
New Trends on Landing Gear Systems for Aircrafts: Case Study	288
<i>Rodrigo Amorim, Luís Coelho, and M. L. Alves</i>	
Author Index	301