GCSM

19th Global Conference on Sustainable Manufacturing

"Sustainable Manufacturing as a Driver for Growth"

December 4 to 6, 2023

ITBA Sede Distrito Financiero

Buenos Aires, Argentina

CONFERENCE BOOK

» PREFACE

The Organizing Committee of the 19th Global Conference on Sustainable Manufacturing (GCSM) is happy to meet you in Buenos Aires, Argentina. This conference is jointly organized and hosted by the Technische Universität Berlin, the Fraunhofer Institute for Production Systems and Design Technology (IPK) and the Instituto Tecnológico de Buenos Aires (ITBA).
The GCSM serves as a forum for universities, research institutes and industry on their activities related to sustainable manufacturing. Mutual intellectual dialogue based on initiatives coping with the challenge of environmental, social and economic sustainability in the global framework coin the conference. Plenary keynote speeches by experienced personalities from academics and industry, technical presentations in respective sessions and workshops of student teams from different countries offer new insights and chances for exchange of ideas. Session contents on product design, manufacturing processes and systems, and on crosscutting technological topics as education, business models, technology innovation are integrated under the umbrella of sustainability. Over 100 contributions will be presented in parallel sessions. They are authored and co-authored by personalities from more than 20 countries representing all continents of the globe.

Welcome to GCSM 2023 in Buenos Aires!

Best regards,

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(Local Chairman)

Prof. Dr.-Ing.
Franz Dietrich
(International Chairman)

Prof. Dr.-Ing.
Holger Kohl
(International Chairman)

Prof. Dr.-Ing.
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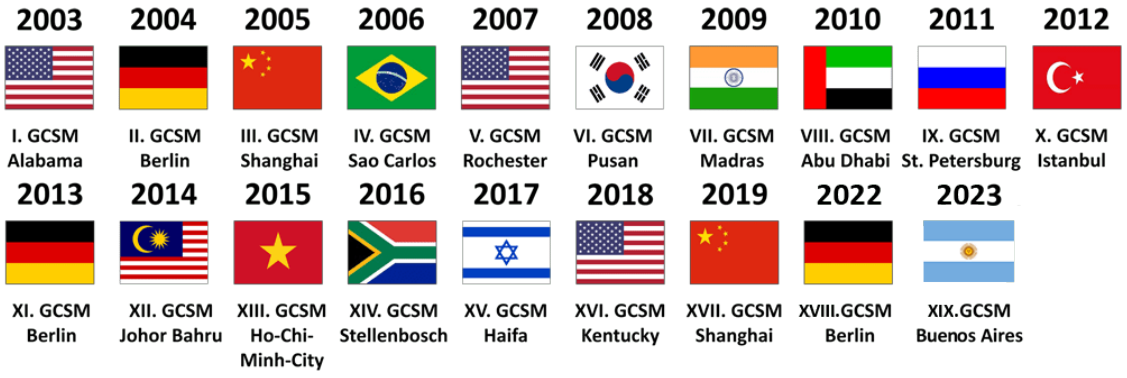

time\date	December 4, 2023			December 5, 2023			December 6, 2023		
8:00	Registration & Reception			Reception			Reception		
8:30	Conference Opening *(Conference Chairmen)*			Keynote Prof. Peihua Gu (Tianjin University) *(Smart and Sustainable Manufacturing Review and Future Perspectives)*			Keynote Prof. Badurdeen (University of Kentucky) *(Circular Product Design for Next Generation Manufacturing: Assessment Methods and Implementation Strategies)*		
9:00	Keynote Prof. Seliger (TU Berlin) *(Chances and Limits of Sustainable Manufacturing)*			Keynote Prof. Hauschild (TU of Denmark) *(Relative and absolute perspectives on sustainability in manufacturing)*			Keynote Prof. Trabasso (SENAI) *(Additive Maintenance™: a way forward to sustainable manufacturing)*		
9:30	Keynote Prof. Patricio Neffa (ITBA) *(Green Electrons and molecules for sustainable manufacturing: Energy Transition in the shop floor)*			Keynote Dr. Barbara Frei-Spreiter (Schneider Electric) *(Sustainable manufacturing: the pivotal role of Industry 4.0 technologies)*			Keynote Ms. Mary Esther Asheri (Fraunhofer IWU) *(Joint Electrolyser Production as the Basis for a Hydrogen Bridge between Argentina and Germany)*		
10:00	Keynote Prof. Nabil Nasr (RIT) *(Accelerating the Transition to Circular Economy Through Transformational Technologies)*			Keynote Prof. Jawahir (University of Kentucky) *(A Metrics-based Transformative Approach for Developing and Implementing Sustainable Additive Manufacturing)*			Keynote Mr. Nigel Worsnop (Tenaris) *(Approaches to Sustainability at Tenaris)*		
10.30	Coffee Break			Coffee Break			Coffee Break		
11:00 11.30 12:00	***Session 1*** *Energy generation & efficiency*	***Session 2*** *Life Cycle Thinking*	***Session 3*** *Design & Innovation*	***Session 10*** *Education*	***Session 11*** *Technical Processes I*	***Session 12*** *Business Models & Regional Integration I*	***Session 19*** *Repair and Maintenance*	***Session 20*** *Additive Manufacturing*	***Session 21*** *Factory Planning & Production Management II*
12:30	Lunch			Lunch			Farewell & Outlook (GCSM 2024)		
13:00							Lunch		
13:30 14:00 14:30	***Session 4*** *Materials & Resource efficiency*	***Session 5*** *Technical Valuation*	***Session 6*** *Data & Simulation*	***Session 13*** *Student Session*	***Session 14*** *Technical Processes II*	***Session 10*** *Business Models & Regional Integration II*	Tenaris & ITBA Lab Tour		
15:00	Coffee Break			Coffee Break					
15:30 16:00 16:30	***Session 7*** *Remanufacturing*	***Session 8*** *Social Valuation*	***Session 9*** *Data & Learning*	***Session 16*** *Student Session*	***Session 17*** *Technical Processes III*	***Session 18*** *Factory Planning & Production Management I*			
18:00 19:00				Cocktail Reception, Get together at ITBA					
20:00 20:30 …				Tango show, Conference Dinner *(until 24:00)*					

GCSM
19th Global Conference on Sustainable Manufacturing

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» KEYNOTE LECTURES

Keynote 1:

Mon, December 4th, 9:00 – 9:30 a.m., Room 301

Title: Chances and Limits of Sustainable Manufacturing

Prof. Dr.-Ing. em. Günther Seliger

Technische Universität Berlin, Institute of Machine Tools and Factory Management

Abstract

Manufacturing is realizing useful processes and products for human life. Sustainable manufacturing is on production and logistics according to respective values in environmental, social, economic dimensions. The huge potential of manufacturing technology in exploiting sustainable human value creation is exemplarily demonstrated in the series of our Global Conferences on Sustainable Manufacturing. Adequate entrepreneurial development paths within the complex global and local arenas of human politically and economically powerful initiators offer chances for more utility with fewer resources. The doubtful character of human activities spoiling limited resources with irresponsible impact for human survival on globe becomes transparent by scenario-based education related to respective cases in societal arenas. Perspectives and cases within this framework of thoughts coin this contribution.

Keynote 2:

Mon, December 4th, 9:30 – 10:00 a.m., Room 301

Title: Green Electrons and molecules for sustainable manufacturing: Energy Transition in the shop floor

Professor Patricio Neffa

Instituto Technológico de Buenos Aires

Abstract:

The industrial sector has been a major contributor to global energy system CO2 emissions, accounting for a quarter of the total in 2022. The heavy reliance on fossil fuels in this sector has led to severe air-pollution health damage, climate change impacts, and energy security risks. This is particularly concerning in energy-intensive subsectors like cement, steel, chemicals, and paper pulp production.

Achieving a deep and rapid decarbonization of the industry is within reach but require huge transformations. Globally, there is a growing consensus that we must shift away from fossil fuel combustion, prioritize electrification of processes, and substantially increase the utilization of renewable energy sources such as wind, water, and solar, complemented by effective energy storage systems. Fortunately, most of these technologies are readily available in the market and are expected to become even more affordable over time.

This presentation aims to shed light on the current sources of energy utilized in the industry and explores various replacement technologies, emphasizing renewable energy and storage solutions. We will compare their merits and assess their potential to drive the transition towards sustainable manufacturing. Additionally, we will examine some transition highlights, including low-emission hydrogen and synthetic hydrocarbon fuels, as promising alternatives to conventional energy sources.

Despite the promise of a greener industrial sector, challenges lie ahead. We will analyze potential risks, such as social and political obstacles and issues related to raw material access. Nevertheless, we will also explore the numerous opportunities that exist, such as the implementation of supportive regulations, the advancement of clean energy technology manufacturing, the establishment of pilot plants, and other initiatives that foster innovation and collaboration.

Keynote 3:

Mon, December 4th, 10:00 – 10:30 a.m., Room 301

Title: Accelerating the Transition to Circular Economy Through Transformational Technologies

Professor Nabil Nasr

Rochester Institute of Technology, Associate Provost for Academic Affairs & Director, Golisano Institute for Sustainability

REMADE Institute, CEO

Abstract:

In response to growing material demands, recovery, recycling, and remanufacturing present promising areas that can significantly address those challenges. There is a need to address those challenges at a global as well as national and regional levels with clear goals and objectives. In the US, the REMADE Institute was formed as a public/private partnership focused on developing transformational technologies to accelerate the transition to a Circular Economy for materials such as; plastics, metals, fibers and e-waste. The institute is funded through the US Department of Energy with $140 Million in public and private funding for the first 5 years. This presentation will provide an overview of the REMADE Institute and its technology strategy. The presentation will also highlight advancement in the circular economy that could significantly reduce the embodied energy, emissions, and waste and increase material availability associated with industrial-scale materials production and processing. Eliminate and/or mitigate technical and economic barriers that prevent greater material recycling, recovery, remanufacturing, & reuse.

Keynote 4:

Tue, December 5th, 08:30 – 09:00 a.m., Room 301

Title: Smart and Sustainable Manufacturing Review and Future Perspectives

Professor Peihua Gu

Tianjin University, President of International Institute for Innovative Design and Intelligent Manufacturing

Abstract:

Smart manufacturing also known as intelligent manufacturing has been recognized as the major driving force to transform manufacturing industry. The international collaboration on Intelligent Manufacturing Systems (IMS) was initiated by Japan with participation of US, Canada, Australia, and European partners in early 90s. Since Germany introduced Industry 4.0, artificial intelligence, digitalization, big data, cloud computing, internet of things and other related technologies have been supporting rapid development and deployment of smart manufacturing technologies. As the international communities have been experiencing the extreme weather conditions in recent years, the implementation of Paris Agreement has received significant attention from many countries. The international societies have realized that AI technologies and the carbon neutrality commitments will have profound impact on not only manufacturing industry, but also almost all other sectors of the society. This keynote lecture will provide a brief historical review of IMS, the current technological development and the future perspectives of smart manufacturing in low carbon and industrial metaverse era.

Keynote 5:

Tue, December 5th, 09:00 – 09:30 a.m., Room 301

Title: Relative and absolute perspectives on sustainability in manufacturing

Professor Michael Zwicky Hauschild

Technical University of Denmark, Department of Environmental and Resource Engineering
Quantitative Sustainability Assessment

Abstract:

A sustainable development meets the needs of current generations without compromising the abilities of future generations to meet their own needs. Manufacturing plays a central role in helping us meet our needs for food, mobility, housing etc. But which needs are we talking about and how do we ensure that our production activities do not compromise the need fulfilment of future generations? Stability of the climate and ecosystems is an essential precondition for the functioning of our societies, but while we have seen continuous improvements in the eco-efficiency of our technology (delivered service per environmental impact) over the last decades, we have also seen increasing pressure on our environment, and irreversible changes seem imminent if we don't change our ways. For manufacturing this means that we need to shift our focus from relative sustainability (the solutions we develop are more sustainable than what they replace) towards absolute sustainability (solutions that are sustainable – in absolute terms). For climate change the Paris agreement to strive for climate neutrality by 2050 is an example of an absolute boundary that defines environmental sustainability. But we are also in the middle of a deep biodiversity crisis that is caused by a range of other environmental impacts and also here manufacturing needs to orient itself towards technological developments that have the potential to meet the needs of present and future generations within the biophysical limits of our planet.

Keynote 6:

Tue, December 5th, 09:30 – 10:00 a.m., Room 301

Title: Sustainable manufacturing: the pivotal role of Industry 4.0 technologies

Dr. Barbara Frei-Spreiter

Schneider Electric, Industrial Automation, Executive Vice President

Member of the Executive Committee

Abstract:

Advanced Manufacturing technologies and solutions play a crucial role to enable responsible, sustainable, and inclusive business transformation and growth. But: today less than 30% of industrial operations have successfully deployed a digital transformation program at scale. The potential for improvement is stunning.

Technology is available to realize the industries of the future -- but this transformation is also about people and management.

Keynote 7:

Tue, December 5th, 10:00 – 10:30 a.m., Room 301

Title: A Metrics-based Transformative Approach for Developing and Implementing Sustainable Additive Manufacturing

Professor Ibrahim S. Jawahir

University of Kentucky, Institute for Sustainable Manufacturing (ISM)

Abstract:

Additive manufacturing (AM) processes continue to offer unique functional capabilities for diverse applications in industry. In recent years, solid-state additive manufacturing (SSAM) technologies have emerged as an effective alternative to traditional Fusion-based additive manufacturing (FBAM) processes. In SSAM, the additive feedstock material undergoes processing at temperatures below its melting point, avoiding many of the inherent challenges associated with FBAM, including complex microstructure control, undesirable residual stresses, part distortion, build rate and volume limitations, etc. Therefore, SSAM provides an advanced processing route for multi-scale AM of functionally superior components composed of materials and dissimilar multi-materials systems. Furthermore, SSAM enables manufacturing of large components that would otherwise be manufactured by casting or forging (which are highly energy intensive and time-consuming costly processes), while providing repair opportunities for large-scale legacy components and structures (e.g., bridges) and revitalizing aging infrastructure.

Almost all FBAM processes continue to suffer poor energy/resource efficiency, increased waste generation, reduced reusability of materials, and inconsistent and undesirable sub-surface quality, thus demonstrating poor process sustainability and product quality. SSAM processes show significantly improved energy/resource efficiency with material reuse capabilities and offer consistent sub-surface quality for improved functional performance of manufactured components. Published work on sustainability enhancement in AM is limited as they focus on just one or two sustainability measures such as energy consumption and material reuse. A comprehensive methodology for evaluating the overall AM process sustainability is largely lacking, thus limiting the development of advanced, innovative, and sustainable AM processes.

This presentation will demonstrate the benefits of recently developed novel, metrics-based product/process sustainability evaluation approach for transforming the current AM processes into sustainable AM focusing on the two major additive manufacturing processes: (a) Additive Friction Stir Deposition (AFSD); and (b) Cold Spray AM (CSAM). These processes offer enhanced process sustainability through reduced energy consumption and material wastes, with more effective material

utilization, while potentially utilizing scrap waste as material feedstock (offering a “waste-to-value” proposition), while significantly improving the additively manufactured product quality for enhanced functional performance. A comprehensive and quantitative analysis of sustainability performance in AM processes, and the resulting components’ quality and performance, would be expected to make a major contribution towards developing and implementing next generation sustainable additive manufacturing processes.

Keynote 8:

Wed, December 6th, 8:30 – 9:00 a.m., Room 301

Title: Circular Product Design for Next Generation Manufacturing: Assessment Methods and Implementation Strategies

Professor Fazleena Badurdeen

University of Kentucky, Institute for Sustainable Manufacturing (ISM)

Abstract:

Restoration and regeneration are key pillars of the Circular Economy, aimed at minimizing the significant resources consumed and waste generated to meet the needs of a growing global population. While Circular Economy strategies are deployable at different levels from cities and regions to entire nations, enduring benefits and impactful transformations are not feasible unless implemented at the micro or product level. The design and deployment of products following Circular Economy principles is the nucleus for next generation manufacturing that will enable effective macro level Circular Economy transformations, paving the way for value creation for all stakeholders for long-term sustainable development. This presentation will critically examine the fundamental requirements for characterizing circularity at the product level. To operationalize circular product design, interventions are required at critical points across the product development process. Readiness or adaptability of product designs for circularity integration and symbiosis-driven collaborative practices for design and manufacturing can enhance capabilities for promoting product circularity. Industry 4.0 and related novel emerging technologies such as generative AI have the potential to offer superior capabilities for advancing next-generation circular product design and sustainable manufacturing. Novel, comprehensive and industry-relevant approaches for assessing product circularity are also vital to evaluate the effectiveness of the designs, manufacturing and their performance over the total lifecycle. This presentation will cover these aspects as well as international initiatives for standardization of principles for circular product design, to facilitate the widespread deployment of Circular Economy practices.

Keynote 9:

Wed, December 6th, 9:00 – 9:30 a.m., Room 301

Title: Additive Maintenance™: a way forward to sustainable manufacturing

Dr. Luís Gonzaga Trabasso

SENAI Innovation Institute for Manufacturing Systems and Laser Processing, Chief Research Officer

Abstract:

The conventional maintenance process takes various steps until a component is actually replaced by a new one either because a failure or end-of-life. Special attention must be given for the buildup of the inventory. A part must be manufactured, transported, stored …just in case it is needed. Contrariwise, additive maintenance is based upon the use of artificial intelligence for failure prediction and metal additive manufacturing (either Laser Direct Energy Deposition or Laser Power Bed Fusion) for supplying the maintenance parts on demand.

Keynote 10:

Wed, December 6th, 9:30 – 10:00 a.m., Room 301

Title: Joint Electrolyser Production as the Basis for a Hydrogen Bridge between Argentina and Germany

Ms. Mary Esther Asheri

Fraunhofer Institute for Machine Tools and Forming Technology, Referenzfabrik.H2

Abstract:

In the context of the demanding energy transition and decarbonization, hydrogen has gained prominence as a partner of green energy. However, a challenge persists concerning the fulfillment of ecologically sustainable hydrogen production, a difficulty that hinders the establishment of a hydrogen-centric economy worldwide. The central element is Electrolysers. These are systems that use green energy to separate water into hydrogen and oxygen. The task is as fast as possible to revolve around the establishment of an efficient and economic amplification of electrolyser manufacturing on a large scale.

The Referenzfabrik.H2 is actively addressing these challenges, deeply linked to the upscaling of electrolyser and hydrogen systems production, employing technologies and advancements development drawn from partners from industrial sectors and Fraunhofer IWU. Operating as a cooperative consortium, the Referenzfabrik.H2 functions as a value chain community of specialized companies from several action areas and expertise, thereby fostering an environment conducive to effective collaborative engagement and the reciprocal dissemination of knowledge related to the ramp-up production of electrolyser components in a large-scale aiming accelerated cost-efficient and scalable electrolyser production.

The Referenzfabrik.H2 wants to serve as a bridge between Germany and Argentina in the domain of green hydrogen. With Argentina's renewable energy potential, the Referenzfabrik.H2 can catalyze effective partnerships, accelerating Argentina's and Germany’s green hydrogen ambitions while contributing to global sustainability objectives.

Through joint efforts, the initiative attempts to develop streamlined manufacturing processes, innovative automation and quality assurance solutions, and standardized techniques, ultimately driving the transformation of the hydrogen industry towards competitive hydrogen production and its acceptance.

Keynote 11:

Wed, December 6th, 10:00 – 10:30 a.m., Room 301

Title: Approaches to Sustainability at Tenaris

Mr. Nigel Worsnop

Vice-President Marketing of Tenaris

Abstract:

The final Keynote will be given by Nigel Worsnop, Marketing Director at Tenaris, which is a industrial company with manufacturing steel pipes for the energy industry all around the world. With their particular focus on their operations in Latin America, they are focusing on the long-term perspectives and thus always have had embedded sustainability principles in their business processes. However, rising issues concerning the climate crisis especially force companies in the steel and energy sectors to reevaluate and adapt their sustainability strategies. Tenaris, as a company on the nexus of the steel and energy industries, is particularly challenged. In the keynote, these challenges will be addressed and participants of the GCSM are invited to join for a visit at Tenaris, meeting the President of Operations in Argentina, and learning firsthand how sustainability concepts are applied in the operations.

Mon, 4th December- 11:00 - 12:30		
Paper Session 1 Sustainable Manufacturing Processes - **Energy generation & efficiency**	**Paper Session 2** Sustainable Materials & Products - **Life Cycle Thinking**	**Paper Session 3** Crosscutting Topics in Sustainable Manufacturing - **Design & Innovation**
Potentials for Energy Savings and Carbon Dioxide Emissions Reduction in Cement Industry (ID 23)	A Systems-based Framework with Attributes, Indicators and Metrics for Product Circularity Assessment (AIM-PCA) (ID 196)	Product-Production-CoDesign Thinking for sustainable manufacturing (ID 108)
Optimization of the melting furnace unit in an Italian aluminum foundry to reduce gas methane consumption (ID 202)	Sustainability Data Map: A Framework for the data-based Assessment of the Product Carbon Footprint of Technical Products (ID 48)	Technology radar for a sustainable biological transformation in the manufacturing industry (ID 74)
Development of a Minimalistic Smart Sensor System for Motion Measurement of Wind Turbine Towers (ID 152)	Identification of Lightweighting Potentials towards more Sustainable Products via the Functional Lifecycle Energy Analysis (FLCEA) (ID 19)	Research on the development mode and path of green design of industrial products in China (ID 129)
Design of an Energy Harvesting System for an implantable cardiac Pacemaker (ID 5)	Initial steps in implementing a Blockchain Node for Green Hydrogen Origin Certification (ID 204)	Efficient and sustainable production of electrical machines - achieving a higher slot fill factor through an innovative forming process chain (ID 208)
A mathematical model for the collection of pathological wastes (ID 77)	Life cycle assessment of a circular saw blade for wood processing (ID 193)	Collaborative development of design requirements for designing assistive technology devices for early infancy children (ID 149)

Paper Session 1: Sustainable Manufacturing Processes - Energy generation & efficiency
Mon, 4th Dec - 11:00 - 12:30, Room 401

Potentials for Energy Savings and Carbon Dioxide Emissions Reduction in Cement Industry (ID 23)

Shoaib Sarfraz[1], Ziyad Sherif[1], Michal Drewniok[2], Natanael Bolson[3], Jonathan Cullen[3], Phil Purnell[2], Mark Jolly[1] and Konstantinos Salonitis[1]

[1]*Sustainable Manufacturing Systems Centre, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK*

[2] *School of Civil Engineering, Faculty of Engineering and Physical Sciences, University of Leeds, Woodhouse Ln., Woodhouse, Leeds, UK*

[3] *Department of Engineering, University of Cambridge, Trumpington Street, Cambridge, CB2 1PZ, UK*

Abstract: Cement production accounts for 7% of global carbon dioxide emissions, 3 to 4% of greenhouse gas emissions, and 7% of global industrial energy use. Cement demand is continuously increasing due to the rising worldwide population and urbanisation trends, as well as infrastructure development needs. By 2050, global cement production is expected to increase by 12 to 23% from its current level. Following the net-zero carbon 2050 agenda, both energy and emissions must be significantly reduced. Different production routes exist to produce cement that differs in energy intensity as well as carbon intensity. Similarly, a range of values exists related to energy and emissions for the major cement production stages i.e., raw meal preparation, clinkerisation and cement grinding. The same is the case with cement types produced. This study presents a literature review-based investigation and comparison of cement production practices in terms of energy consumption and CO2 emissions. This will provide perspectives to the cement industry by identifying approaches that are the least energy and emissions intensive.

Keywords: Cement Production, Clinker, Energy, CO2 Emissions, Net-Zero Carbon

Optimization of the melting furnace unit in an Italian aluminum foundry to reduce gas methane consumption (ID 202)

Jessica Rossi[1] and Augusto Bianchini[1]

[1] *Department of Industrial Engineering, University of Bologna, Via Fontanelle 40, 47121, Forlì, Italy*

Abstract: The foundry industry is one of the most energy-intensive industrial sectors. Consequently, the energy cost can reach 7-15% of the cost of the operations. Among all the types of energy used, the most significant part of energy consumption is associated in Italy with gas methane in different typologies of melting furnaces. According to the treated material (e.g., aluminium, steel, cast iron), the foundry process can vary; however, some operations characterize the entire sector, such as the metal melting phase, which is the most energy-intensive stage of the process (it can account up to 70% of the total energy consumption of the foundry). The energy crisis, which has affected companies in these years, determines instability and volatility in energy availability and costs and requires implementing some improvements to optimize energy efficiency and reduce consumption. With the aim of investigating the potential energy reduction in the foundry sector, an Italian aluminium foundry has been considered. The analysis consisted of three main activities: (i) Analysis of the process and mapping of energy and resource consumption at the factory level and in each unit; (ii) Quantification of energy and resource consumption at the factory level according to the ViVACE® method; and (iii) Addressing the critical points (energy consumption) to improve the environmental impact of the found

ry. According to this methodology, the optimization of the melting furnace unit has been addressed, allowing the potential saving of gas methane up to 13%.

Keywords: Foundry, Methane, Aluminium, Optimization, Energy efficiency

Development of a Minimalistic Smart Sensor System for Motion Measurement of Wind Turbine Towers (ID 152)

Johannes Rupfle[1,2] and Christian Grosse[1]

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Abstract: The accurate measurement of wind turbine tower motion is crucial for assessing structural integrity, identifying damages, and estimating remaining useful life. In this study, the development of a smart sensor system is presented, which combines acceleration measurements and real-time kinematic measurements to accurately determine the motion of slender structures. The proposed minimalistic sensor setup offers a cost-effective and easily deployable solution. Installed on the top of the wind turbine nacelle, the sensor system collects acceleration data used to calculate the tower motion. Real-time kinematics measurements serve as correction input for a state estimator, to enhance the accuracy and reliability of the motion data. Data gathering and processing occur directly on the sensor node, allowing for efficient transfer. While the current publication focuses on the measurement capability, potential future iterations of the system could allow the evaluation of tension history and changes in natural frequencies, for damage assessment. Test measurements on buildings and wind turbine towers have demonstrated the effectiveness of the system for accurate motion measurements. Beyond wind turbine manufacturing, this sensor system holds potential for application in various industries, including tall buildings and bridges, where the detection of subtle vibrational movements is valuable for structural health monitoring.

Keywords: sustainable manufacturing, life cycle assessment, smart sensor system, wind turbine tower motion, acceleration measurements, real-time kinematic measurements, damage assessment, remaining useful life, structural health monitoring, industry 4.0, internet of things, sustainable development

Design of an Energy Harvesting System for an implantable cardiac Pacemaker (ID 5)

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Abstract: Pacemakers have been in use for a long time to help patients who have heartbeats that are not in sync and also those with arrhythmia to live a normal life. Despite numerous technological advances, pacemakers still have a number of problems due to their use of lithium batteries. Researchers and scientists have always been interested in developing leadless, self-powered pacemakers. Pacemakers may now be implanted in more beneficial shapes that make them more effective throughout the implantation procedure without harming nearby tissue, the development of flexible electronics has made this endeavor feasible. Pacemakers can now be powered by internal

bodily motions and other processes thanks to advancements in energy harvesting devices. A leadless, adaptable, self-powered, and intelligent single chamber pacemaker has been researched using a variety of methodologies and frameworks in this study. The design and simulation of an energy harvesting piezoelectric cantilever beam on background of heart vibration is presented in this work. The forward piezoelectric effect, which transforms the vibration of the heart which provides mechanical energy into electrical energy during the sensing of ambient vibration by the cantilever beam, facilitates the energy harvesting process. The cantilever beam model consists of a tip mass positioned at one end and two piezoelectric layers clamped to a vibrating host structure at the other. A comparison of the computed output properties of the cantilever beam was done using COMSOL Multiphysics. Different features were examined in relation to a range of input parameters which include the cantilever beam's length-to-width ratio, resonance frequency, and load resistance.

Keywords: Pacemaker, Arrhythmia, Piezoelectric, Energy Harvester, Leadless, Implantable, Energy harvester, Cantilever

A mathematical model for the collection of pathological wastes (ID 77)

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Abstract: This study presents a mathematical model for the collection of pathological wastes generated in hospital environments. This type of waste cannot be directly discarded to the landfill because it is potentially infectious, so it must be previously treated to avoid its dangerous factor. For this, a fleet of vehicles must pick up a certain amount of waste from different geographically dispersed sites and deliver everything to a plant where the cleaning process is made. The problem is considered as a Periodic Vehicle Routing Problem (PVRP) given that each location must be visited at a specific frequency. Assuming a weekly planning horizon, the problem involves the following decisions: (i) the visiting days for each site satisfying the required weekly frequency, (ii) the assignment of vehicles to the selected day-site, and (iii) the vehicle routing for each day.
For the later, it is considered that each route begins and ends at the plant and the loaded waste in the vehicle cannot exceed its capacity. In this work, the problem is addressed through a mixed integer linear programming model that simultaneously solves the above-mentioned issues with the objective of minimizing the total traveled distance to reduce the carbon emission.

Keywords: Pathological waste, Periodic Vehicle Routing Problem, MILP

Paper Session 2: Sustainable Materials & Products - Life Cycle Thinking

Mon, 4th Dec - 11:00 - 12:30, Room 501

A Systems-based Framework with Attributes, Indicators and Metrics for Product Circularity Assessment (AIM-PCA) (ID 196)

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Abstract: One of the key aspects of Circular Economy (CE), particularly when focusing on the product level, lies in its emphasis on designing products to facilitate the circulation of resources and maximize value throughout their entire lifecycle. To effectively develop such products an understanding of the characteristics of circular products (CP) is needed. Adopting a systems perspective that considers the total lifecycle and stakeholders involved and recognizing interdependencies among them is essential for identifying factors that characterize CPs. Existing methods for assessing product circularity do not identify all factors that characterize CPs and have limitations in the measurement methods proposed, leading to poor industry adoption. This research aims to develop a systems-based framework with clearly defined attributes, indicators, and metrics for product circularity assessment (PCA) to facilitate more effective design practices for CPs. A two-pronged approach, with industry engagement, is followed to address this gap: first, a systematic analysis of literature is conducted to identify key attributes and establish a clear foundation of what constitutes a CP; secondly, a comprehensive examination of indicators and metrics to evaluate the attributes is undertaken. This paper presents the preliminary systems-based framework for PCA with example attributes, indicators, and metrics, specifically for consumer electronic product circularity evaluation and directions for further research.

Keywords: Circular Economy, Circular Products, Product Circularity

Sustainability Data Map: A Framework for the data-based Assessment of the Product Carbon Footprint of Technical Products (ID 48)

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Abstract: Growing awareness and political regulations increase the pressure on companies to become more sustainable. Manufacturers of technical products in particular face the challenge of decarbonization, as machinery and plants, for instance, have an impact on the emissions of almost all industries. However, information on the Product Carbon Footprint (PCF) is often not transparent for manufacturing companies. Digitalization has proven to be a key enabler, as up to 90% of manufacturers' emissions occur along the value chain, making it impossible to calculate the PCF without data. However, identifying the necessary data and the corresponding IT system is a major challenge, especially for technical products.

The Sustainability Data Map supports the identification and structuring of relevant data and its sources for product carbon footprinting across all phases of the product lifecycle. In addition, the Sustainability

Data Map serves as a workshop-based medium to communicate, integrate and engage all relevant stakeholders in the value chain. It is based on an existing data map that has been extended to include the criteria required for PCF determination. As a result, the Sustainability Data Map enables manufacturing companies to create more transparency about the data needed to assess the PCF of technical products.

Keywords: Sustainability Assessment, Product Carbon Footprint, Data Map, Technical Products

Identification of Lightweighting Potentials towards more Sustainable Products via the Functional Lifecycle Energy Analysis (FLCEA) (ID 19)

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Abstract: In times of increasing material scarcity and still not widespread availability of renewable energy, it is inevitable to seize all opportunities to improve the resource efficiency of any product. In particular, this promotes lightweight design as a key technology to reduce both material and energy consumption across the entire product lifecycle. Therefore, systematically exploiting lightweighting potentials already on a functional level remains a major challenge requiring methods of product development to be applied in the early phase of each development cycle ensuring the implementation of the holistically best solution from a sustainability point of view. Thus, the proposed “functional lifecycle energy analysis” (FLCEA) provides a remedy to effectively implement lightweight design in products by identifying recommendations for action regarding future product generations, resulting in a holistic energy optimization. In this contribution, the methodology is presented in parallel to its implementation in the use case of conceptual designing a semi-mobile handling system. As a result of this study, it was not only possible to identify lightweighting potentials of the system-in-development, but also to analyze technical product functions requiring modifications in view of the circular economy to holistically improve the ecological sustainability of the entire system.

Keywords: Lightweight Design; Design for Sustainability; Functional Design; Energy Analysis; Lifecycle Optimization

Initial steps in implementing a Blockchain Node for Green Hydrogen Origin Certification (ID 204)

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Abstract: In the face of rising concerns about climate change, the energy sector is undergoing a digital transformation. Blockchain technology has emerged as a promising solution to ensure security, traceability, and efficiency in energy management, particularly in certifying the origin of energy.

Various projects in the energy sector are discussed, highlighting how these initiatives are transforming the way energy is produced, distributed, and consumed. The paper concludes with a reflection on the benefits and challenges of implementing blockchain technology in Argentina in the energy sector and suggests directions for future research.

Keywords: Blockchain, Renewable Energy, Energy Certification

Life cycle assessment of a circular saw blade for wood processing (ID 193)

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Abstract: Climate change and its negative consequences are an inevitable topic that strongly affects all industrial sectors as well as private individuals. Therefore, it is necessary to assess and monitor the environmental impact of products, services, and processes. This paper presents a practical application of an LCA for circular saw blade used in wood processing. By considering all stages of the circular saw blade's life cycle, including manufacturing, period of use, and end of life phase, a comprehensive assessment of its environmental impact is provided.

The software SimaPro was utilized to conduct the LCA, which involved evaluating each individual element of the circular saw blade. As a result of this study, the environmental impact of the various components of a circular saw blade was quantified, enabling an assessment of its cumulative potential environmental impact. Consequently, recommendations for more sustainable manufacturing, use and disposal of circular saw blades in wood processing are derived from the findings, contributing to an overall improvement in their environmental impact.

Keywords: Life Cycle Assessment (LCA), climate change, SimaPro, impact assessment, circular saw blade

Paper Session 3: Crosscutting Topics in Sustainable Manufacturing - Design & Innovation

Mon, 4th Dec - 11:00 - 12:30, Room 701

Product-Production-CoDesign Thinking for sustainable manufacturing (ID 108)

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Abstract: Manufacturing needs to contribute towards a sustainable future for the sake of preserving and enriching humanity on planet earth.

This goal is enshrined in the Sustainable Development Goals (SGD) set forth by the United Nations. SGD 9 aims at building a resilient, innovative and sustainable industrialization. SGD 12 ensures sustainable consumption and production patterns. Currently, manufacturing falls short of achieving these targets as product design and production engineering operate individually and sustainable practices are not focused. This industrial problem is reflected in the absence of holistic approaches that aim at sustainable production by providing applicable methods. To address this challenge, we propose Product-Production-CoDesign (PPCD) Thinking. With a clear focus on sustainability we delineate PPCD Thinking from Design Thinking and extend the notion towards manufacturing.

It encompasses linear manufacturing (SGD 9) and circular production (SGD 12). Four case studies illustrate this software defined production enable PPCD Thinking and its customizability. In a nutshell, Product-Production-CoDesign Thinking, thus, can contribute to moving towards sustainable manufacturing and net zero.

Keywords: sustainability, design thinking, manufacturing

Technology radar for a sustainable biological transformation in the manufacturing industry (ID 74)

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Abstract: Bio-inspired, bio-integrated, bio-intelligent product and production systems are new research approaches aimed at achieving sustainability in manufacturing. For the industrial application of new technological solutions, it is crucial to convey their added value from not only an economic but also an environmental perspective. The evaluation of their technological readiness plays an important role in implementation. This paper presents a technology radar developed and evaluated within German research project BioFusion 4.0 involving 13 industry and research partners. The paper outlines the development approach and its application by means of three technological examples. The technologies are categorized and assessed using four significant attributes of an effective biological transformation: (1) the mode of action (bio-inspiration, bio-integration, and bio-interaction); (2) the transformative character and (3), the Technology - and (4) Sustainability Readiness Level. The technology radar comprises a step-by-step procedure to assess a technology by each criterion to enable different stakeholders, such as production planners or product developers to evaluate and identify suitable technologies according to their needs and business strategy. The application of the technology radar is demonstrated on the exemplary technologies of a digital twin

with integrated life-cycle assessment, situation awareness monitor for networked production systems and bio-based 3D printing.

Keywords: Technology Assessment, Biological Transformation, Sustainability Readiness Level, Digital Twin, 3-D Printing, Holistic Production Systems

Research on the development mode and path of green design of industrial products in China (ID 129)

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Abstract: Green product design takes the coordinated development of humans and nature as the fundamental goal. The green design of industrial products plays the first lever function to start the sustainable development of industry and promotes the construction of green manufacturing system. As one of the world's largest consumer markets, China's green design of industrial products is of great significance to slowing down global warming and addressing global climate issues. By combing through China's nationwide green design initiatives, this paper interprets China's pre-planned green design concepts, analyzes the green design paths and development patterns of China's industrial products, summarizes achievements and lessons learned, and demonstrates future development.

Keywords: Manufacturing, Design, Sustainable development, Management

Efficient and sustainable production of electrical machines - achieving a higher slot fill factor through an innovative forming process chain (ID 208)

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Abstract: With the increasing electrification of mobility and the associated growing demand for electric machines, issues of efficient and resource-saving production and operation are becoming ever more central. Therefore, it is important to optimize the design of components, materials and the assembly of electric machines. An example, described in the paper, shows how to increase the slot fill factor of a stator. By optimising the wire content in the slots, electric machines can be made smaller or, at the same size, operate more powerfully resp. efficiently. Various applicable production methods have different drawbacks such as low productivity, high energy and resource consumption, and restrictions for geometric design. Here, forming technology offers remedy in the utilization of material with simple tools and its suitability for mass production. This paper shows the analysed process chain developed at Fraunhofer IWU for the forming-based production of coils with trapezoidal cross-sectional geometry. The investigation results provide a more sustainable structure and an efficient process chain.

Keywords: Forming, electric machines, coil, sustainability, process chain

Collaborative development of design requirements for designing assistive technology devices for early infancy children (ID 149)

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Abstract: This article presents the development of product requirements in the context of an assistive technology innovation project. It is emphasized that assistive technology plays a fundamental role in the development of sustainable products and environments, as it enables the inclusion and autonomy of people with disabilities, ensuring that all solutions are accessible and efficient. The initial stages of new product development are considered critical due to the need to define requirements that will guide the design process. The challenge in formulating these requirements lies in the contradiction between determining which criteria and factors should accompany the project at a stage where the understanding of the object and the problem is still limited. The methodological approach is primarily based on a descriptive method of the design process leading to the definition of requirements. The results are mainly divided into four topics: project description, description of the stakeholders and actors involved in the project, description of the process of defining design requirements, and finally, the presentation of the requirements developed in the project context. These results can contribute to two main ways: by sharing the defined requirements and by presenting a process of collective construction of design requirements.

Keywords: assistive technology, design, child.

Mon, 4th December - 13:30 - 15:00		
Paper Session 4 Sustainable Manufacturing Processes - **Materials & Resource efficiency**	**Paper Session 5** Sustainable Materials & Products - **Technical Valuation**	**Paper Session 6** Sustainable Manufacturing Systems - **Data and Simulation**
Per- and polyfluoroalkyl substances: an environmental challenge with emerging alternatives for remediation (ID 18)	Feasibility Study and Economic Evaluation of Direct Contact Prelithiation of Lithium-Ion Batteries (ID 115)	Digital technologies enabling resilience in manufacturing networks (ID 136)
Algae-based phlorotannins as sustainable feedstock for epoxy resin formulation (ID 35)	Environmental Impact Assessment of Manufacturing of SiC/SiC Composites (ID 57)	Sustainable Industrial Workstation Design in the Context of Industry 5.0: An Agent-Based Modeling Approach. (ID 54)
A circular use of oil by Double Separation Technology and its sustainable impact comparing to conventional industrial oil usage (ID 205)	Scenario-based Life Cycle Assessment of an Automotive Wire Harness (ID 98)	Combined evaluation of digitization and sustainability maturity of small and medium sized enterprises (ID 82)
Development of a pre-treatment process for EPS-ETICS to enable a solvent-based recycling (ID 42)	Life Cycle Assessment of a Reconfigurable Vibrating Screen Manufacturing Process through a Simulation-based Approach (ID 166)	Data-driven approach for a continuous information flow in a closed-loop supply chain (ID 87)
The impact of fibre architecture preservation on the mechanical properties of recycled CFRP with different woven fibre architectures (ID 109)	Life Cycle and Cost Assessment of CO2 Assisted Hard Turning Of AISI 52100 in Comparison to Conventional Cooling Techniques (ID 117)	Optimizing GHG-Emissions in a Milling Process by Integrating Electricity Mix Data into Manufacturing Parameter Decisions (ID 38)
	Life Cycle Assessment of a prototypical hairpin stator production (ID 165)	

Paper Session 4: Sustainable Manufacturing Processes - Materials & Resource efficiency
Mon, 4th December - 13:30 - 15:00, Room 401

Per- and polyfluoroalkyl substances: an environmental challenge with emerging alternatives for remediation (ID 18)

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Abstract: Per- and poly-fluoroalkyl substances are a group of synthetic aliphatic compounds containing one or more perfluoroalkyl moieties (CnF2n+1-). Due to their unique surface-active properties and high chemical and thermal stability, they are used in various consumer products such as cosmetics, food packaging, furnishings, and textiles. Their use dates back to the 1940s. Despite their peculiar performances, recent scientific works investigate their sustainability and safety deriving from environmental ubiquity, persistence and bioaccumulation. Indeed, these chemicals are not metabolized in animals and are eliminated mainly through the kidneys, with a low excretion capacity in the case of humans. Many studies conducted worldwide have reported significant serum levels of per- and poly-fluoroalkyl substances in most of the general population, associating them with several health conditions, including hepatoxicity, dyslipidaemia, and endocrine and immunotoxicity outcomes. Besides, new sources of emissions due to degradation phenomena are continuously identified. Consequently, long-chain per- and poly-fluoroalkyl substances have triggered supervising actions and restrictions that fostered research about possible alternatives.

This article aims to screen current European scientific investigations conducted to evaluate the impact of these chemicals on the environment and human health, focusing on food packaging and textile production. Due to the paper's length limitation, not all the scientific literature is described because of the need to leave space to discuss possible substitutes. Relevant studies are reported about implementing sustainability and safety/hazard assessment for per- and poly-fluoroalkyl substances. Eventually, the need to develop new and specific analysis methods is discussed

Keywords: PFASs, Food packaging, Textiles, Life Cycle Sustainability Assessment, Safety Assessment, Hazard Assessment

Algae-based phlorotannins as sustainable feedstock for epoxy resin formulation (ID 35)

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Abstract: Bisphenol A is still the most important chemical for the production of epoxy resins for adhesives, impregnating resins for fiber-reinforced plastics, and the like, but as of today is not bio-based accessible. Furthermore, it is rated as a substance of very high concern and possesses reproductive toxic and endocrine-disrupting properties. Therefore, bisphenol A substitutes are without an alternative. Beneath vegetable oils, phlorotannins (a class of polyphenols) are structurally highly suited for the introduction of epoxy groups. They are largely found in macroalgae which are already being harvested using established routes for alginate production. Phlorotannins thus represent

a promising marine raw material for the chemical industry which otherwise has received little attention in research to date, at least in the field of epoxy resin formulation. Since personal work in the field has just begun, the authors would like to give first a theoretical overview of the process "from algae to epoxy resin", including, among others, phlorotannin extraction and analytical methods, as well as the introduction of epoxy groups. Based on practical experiments, the curing behavior of a phloroglucinol-based epoxy resin as a model substance for algae-derived systems is described, which is evaluated by differential scanning calorimetry and rheometry. Fast-curing blends with high glass transition temperatures were obtained, showing high potential for future industrial application.

Keywords: phlorotannins, epoxy resin, algae

A circular use of oil by Double Separation Technology and its sustainable impact comparing to conventional industrial oil usage (ID 205)

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Abstract: Currently industrial oil is considered as a consumable material and used in a linear way: it gets discarded and replaced with new oil when the oil degrades and often loses its desired properties. This is unsustainable and can have hidden, indirect costs relating to productivity and product quality caused by wear on machinery due to degraded industrial oil properties. SKF RecondOil Double Separation Technology (DST) enables regeneration and reuse of industrial oil by removing contaminants and thereby increasing the lifespan of the oil. Such circular use of oil makes industrial oil an asset and can generate monetary and environmental benefits. A lifecycle-based study has been carried out to map and compare the climate impact of the SKF RecondOil DST process to a conventional industrial oil cycle. The results show that a reduction of more than 96% percent of CO2-eq. per m3 oil can be achieved. Furthermore, the results also show that the SKF RecondOil DST processes use less fossil resources during the life cycle compared to a conventional industrial oil cycle. This paper will introduce DST, its applications, and discuss its future development based on the results obtained.

Keywords: circular use of oil, Double Separation Technology (DST), Life cycle assessment (LCA)

Development of a pre-treatment process for EPS-ETICS to enable a solvent-based recycling (ID 42)

Sebastian Lumetzberger[1] , Andreas Lehner[1] , Selina Möllnitz[2] , Gernot Peer[3] , Stephan Keckeis[1] , Roy Huisman[1] , Laura Kasinger[1] , Sebastian Schlund[1,4]

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Abstract. Large quantities of HBCD-containing Expanded Polystyrene (EPS) had been used in External Thermal Insulation Composite Systems (ETICS) from the 1970s until the flame retardant HBCD was banned in 2016 for being a persistent organic pollutant (POP). According to the Basel Convention, a solventbased process is the best available technology for POP-containing waste. Such processes are subject to an impurity limit, thus requiring a pre-treatment of the input material. Therefore, a sequence of comminution and sorting technologies was designed and tested with real-life ETICS

demolition waste. Three specimens were used as input material. Following an initial analysis, the demolition waste was comminuted, examined, and a sorting technology was selected. The resulting material fractions were weighted and analysed. The lightweight fraction (target: sole EPS) was additionally tested for its purity. The designed process achieved an efficient material disintegration and separation resulting in a purity of the lightweight fraction of up to 93 wt.-%. This result represents a major step towards the circularity of EPS via solvent-based recycling.

Keywords: Pre-treatment, Solvent-based recycling, Expanded Polystyrene

Reducing the down-cycling of carbon fibre: An observation on preserving different woven fibre architectures (ID 109)

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Abstract: The growing use of carbon fibre reinforced polymers (CFRP) in the aerospace and wind industries is leading to increases in waste carbon fibres. The current recycling practice for this waste results in significant reductions in material properties. Preserving the reinforcement architecture of carbon fibre has the potential to enhance the mechanical reinforcement capability of the recycled fibre. Nevertheless, the impact of this approach on different woven fibre architectures with varying material characteristics remains unclear. This study presents an observation on applying fibre architecture preservation to the recycling of carbon fibres in two woven fibre architectures, namely twill and satin weaves. Carbon fibres are recycled by a pyrolysis technique and remanufactured into recycled CFRP. Flexural tests indicate increases in the flexural properties of CFRP with twill and satin weaves after recycling, differing from the results for plain weave in a previous study. The results suggest potential influences of weave architectures on the material compositions of the recycled composites, resulting in different flexural properties. Further research is encouraged to investigate the potential correlations and provide deeper insights into the use of this approach to reduce the down-cycling of various types of carbon fibre.

Keywords: Carbon Fibre Recycling, Woven Fabrics, Flexural Properties

Paper Session 5: Sustainable Materials & Products - Technical Valuation Mon, 4th December - 13:30 - 15:00, Room 501

Feasibility Study and Economic Evaluation of Direct Contact Prelithiation of Lithium-Ion Batteries (ID 115)

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Abstract: The increasing need for energy storage across various sectors drives the growing demand for high-performance lithium-ion batteries. Prelithiation has emerged as a promising approach to enhance the capacity and cycle life of lithium-ion batteries. This study investigates the technical feasibility and economic viability of a scalable, roll-to-roll prelithiation process. Using an evaluation methodology adapted from literature, a comprehensive feasibility study and economic evaluation were conducted, considering the industrial-scale implementation of the process. The evaluation demonstrates that the direct contact prelithiation process utilizing lithium foil is technically feasible and suitable for industrial application. The economic viability of the process heavily relies on the lithium price, which constitutes a significant cost factor. The direct contact prelithiation process offers substantial benefits in terms of capacity and cycle life, resulting in enhanced cost-effectiveness of prelithiated lithium-ion batteries. The feasibility study and economic evaluation provide valuable insights implementing direct contact prelithiation as a viable strategy to improve lithium-ion battery performance. The findings contribute to advancing battery technology, manufacturing processes, and overall economic efficiency for diverse applications.

Keywords: Prelithiation, Lithium-ion battery, Battery production, Feasibility study, Economic valuation

Environmental Impact Assessment of Manufacturing of SiC/SiC Composites (ID 57)

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Abstract: SiC/SiC composites have attracted increasing attention in various applications such as turbine blades, exhaust nozzles, and combustor chambers, due to their exceptional mechanical and thermal properties. However, the environmental impact of these composites across their life cycle is an important aspect that needs to be evaluated to support their responsible development and use. In this study, a life cycle assessment of SiC/SiC woven laminate ceramic matrix composites to quantify their environmental impacts from cradle-to-gate was conducted. Three different manufacturing methods to produce SiC/SiC woven laminates were researched: chemical vapour infiltration (CVI), pyrolysis of a preceramic polymer (PIP), and melt infiltration (MI). The Life Cycle Assessment approach was utilized to identify the effect outcomes for each process, analysing the raw material extraction, raw material processing, and final product manufacturing phases to develop the environmental impact assessment. The study's outcome showed that CVI had the lowest average environmental impact between the two methods.

Keywords: SiC/SiC Ceramic Matrix Composites, Life Cycle Assessment, Environmental Impact

Scenario-based Life Cycle Assessment of an Automotive Wire Harness (ID 98)

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Abstract: Wire harnesses are one of the the largest purchased part for many automotive Original Equipment Manufacturers (OEMs). They are highly complex assembly products, consisting of hundreds of wires, electrical connectors, electronic parts, and ancillary materials such as tape. Assembly still is a largely manual process, as the complexity of the wire handling and low level of standardization and digitization pose a challenge to automation efforts. Wire harnesses are expected to increase in complexity and size due to current developments in the automotive sector, namely electromobility, autonomous driving, and digitalization. As a result, the importance of these products to the overall environmental impact of vehicles is likely to increase, with copper playing a significant role. In this study, the environmental impacts of a rear door wire harness are quantified by performing a Life Cycle Assessment (LCA), considering the life cycle from cradle to gate and based on different supply chain scenarios. The impact of sourcing and transport is shown and potential for improvement is derived, especially with regard to reshoring and automation

Keywords: LCA, reshoring, wire harness, supply chain, sustainability

Life Cycle Assessment of a Reconfigurable Vibrating Screen Manufacturing Process through a Simulation-based Approach (ID 166)

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Abstract: The purpose of this study is to describe the environmental impact of a reconfigurable vibrating screen (RVS) based on each sub-system of the machine. GaBi software was used as a Life Cycle Impact Assessment (LCIA) tool and the LCIA was performed with the guidance of the ISO 14044 standard. The CML method includes classification, characterisation, and normalisation. This was used to calculate several sorts of balances and aids in the aggregation of the findings. The results indicate The emission into the sea was found to be 3.729 kgN-eq. while the emission into fresh water (eco-toxicity) was found to be 2064.418 CTUe. Furthermore, the emission into air with potential for ozone depletion was found to be 81.71 kgCFC-11-eq while the emissions from deposited goods was found to be 36.144 CTUh. Finally, the depletion of abiotic resources (depletion of non-fossil resources such as minerals and metals) was found to be 2152.494 kgSb-eq. The results further show that the development of the vibrating screen produces significant emissions to the fresh waters compared to other indicators. The impact was majorly because of resource usage during the production phases. The findings of this study may be useful for improving the sustainability of the vibrating screens throughout its lifecycle.

Keywords: Environmental Impact Assessment, Life Cycle Impact Assessment, Reconfigurable Vibrating Screen, Sustainability

Life Cycle and Cost Assessment of CO2 Assisted Hard Turning Of AISI 52100 in Comparison to Conventional Cooling Techniques (ID 117)

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Abstract: The use of cryogenic CO2 as a cutting fluid is a promising sustainable manufacturing technology capable of substituting oil-based emulsions during hard turning, showing a significant potential for both productivity improvement and environmental impact reduction. While previous works have focused on the assessment of the technical impact of the cryogenic CO2 on the process and quality performance, the present paper faces the evaluation of both the environmental and economic impact of this manufacturing technique. By the application of Life Cycle Assessment (LCA) methodology and Return-on-Investment (ROI) calculations for different manufacturing scenarios, the environmental and economic performance of the cryogenic CO2 cooling technique is evaluated in comparison to conventional cooling. Results indicate that the application of the cryogenic cooling can be successful depending on the manufacturing scenario. The performed analysis shows the possibility to identify the cases where the use of cryogenic CO2 would outperform conventional cooling strategies, proving a valuable methodology for minimizing the environmental impact and ensuring the cost effectiveness during the design phase of industrial turn-key projects for hard-turning operations.

Life Cycle Assessment of a prototypical hairpin stator production (ID 165)

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Abstract: Current forecasts indicate a significant increase in demand for electric traction drives, including the corresponding impact on the environment. Modern motor designs and sustainability assessments thereof focus on efficiency in use, among other reasons motivated by the major environmental impact during this phase caused indirectly by carbon intensive energy production. However, due to the use of limited resources and energy intensive manufacturing processes, the production phase is increasingly critical for a sustainable life cycle of electric motors. In the prototyping stage, a major part of future product development, the direction for the sustainability of a product throughout its life cycle is being set. Therefore, the prototyping stage can already be used to gather useful insights into the environmental impact of a future product and its production system. In this research, a life cycle analysis of a prototypical production of one of the main components of the electric drive, the stator, is performed. The process chain of stator production of the research project HaPiPro² is investigated in two parts: First, a Life Cycle Inventory is conducted by direct data collection supplemented by the data sets from the commercial database ecoInvent v3.91 as well as publicly available data from other research. Subsequently, a Life Cycle Impact Assessment (LCA) is performed with the tar get of a comprehensive and accurate evaluation of the input and output flows of the prototypical production. The assessment is focused on the impact categories global warming potential (GWP), terrestrial acidification, human toxicity and freshwater ecotoxicity.

Keywords: Life cycle assessment, hairpin stator, e-motor prototyping

Paper Session 6: Sustainable Manufacturing Systems - Data and Simulation
Mon, 4th December - 13:30 - 15:00, Room 701

Digital technologies enabling resilience in manufacturing networks (ID 136)

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Abstract: Unforeseen events have the potential to cause disruptions throughout the entire manufacturing value chain, ranging from interruptions in production processes on the shop floor level to shutdowns in the supply chain and logistics. These disruptions increase the necessity for the establishment of manufacturing networks that prioritize cooperation and circularity to strengthen resilience, predict and counteract such impacts. This paper provides an overview of the main digital technologies required to create a resilient and sustainable manufacturing network and the implementation of the Manufacturing as a Service (MaaS) approach. For each digital technology, a synthetic characterization is provided, with respect to requirements, exemplary applications and involved standards. Challenges on the use of such technologies are presented and suggestions for future developments on the integration and deployment of digital technologies with the aim of achieving resilience in manufacturing networks is described.

Keywords: Digitally Integrated Production, Resilience, Supply Chain, Circularity, Manufacturing networks, Sustainability, Manufacturing as a Service

Sustainable Industrial Workstation Design in the Context of Industry 5.0: An Agent-Based Modeling Approach. (ID 54)

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Abstract: As the world transitions into Industry 5.0, characterized by the integration of advanced technologies and automation, sustainable workstation design plays a crucial role in creating environmentally conscious work environments. This paper explores sustainable industrial workstation design within the context of Industry 5.0 using Agent-Based Modeling. By simulating the behavior of individual workstations as autonomous agents, this approach allows for a detailed examination of workplace interactions and dynamics. The paper highlights the importance of sustainability in the workplace, outlines key considerations for sustainable workstation design, and discusses the potential benefits of implementing sustainable practices in Industry 5.0. Additionally, it investigates the application of emerging technologies and innovative strategies to create sustainable work environments. Utilizing Agent-Based Modeling, organizations can gain insights into the effects of sustainable workstation design on energy efficiency, employee well-being, and productivity. The findings contribute to a deeper understanding of sustainable workstation design in Industry 5.0 and inform decision-making processes towards creating more sustainable workplaces.

Keywords: Industry 5.0, Sustainability, Agent Based Modeling, Smart Manufacturing.

Combined evaluation of digitization and sustainability maturity of small and medium sized enterprises (ID 82)

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Abstract: Sustainability and digitalization are of high importance for companies to stay competitive and cope with market requirements from internal and external stakeholders. Especially the current changes in reporting standards and frameworks increase pressure to quickly adapt internal processes and acquire the relevant data. In this context, Industry 4.0 (I4.0) is discussed to enable companies to also foster sustainability. But many small and medium sized enterprises (SME) lack of experience and capacity and need support from experienced partners to develop suitable strategies and implement technologies. Appropriate support needs to comprise evaluation of the current level of knowledge and to derive suitable actions for improvement. Maturity models (MM) are well-established to initiate and support the transformation of corporate structures. There are many models available that support digital and sustainable transformation, but no models that include both dimensions comprehensively. This results in missed opportunities to foster sustainability already during digitization strategy development and vice versa. Hence, this contribution introduces a combined model for both domains and systematically describes the extension of an existing digitalization MM (DMM) that also considers rebound effects. The MM is tested within an industrial use case. The results are evaluated and discussed for further development of the model and workflow.

Keywords: Digitalization, Sustainability, Maturity Model

Data-driven approach for a continuous information flow in a closed-loop supply chain (ID 87)

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Abstract: Due to the large variety of actors, channels, and materials involved, the processes of the circular economy are very complex. This complexity makes it difficult to maintain consistent data quality throughout the supply chain. Circular processes can only be applied extensively if enough data, for example supplier information, is available. Data and information from suppliers, manufacturers, end-users, and recyclers are not shared transparently through circular processes. One reason is the insufficient support from IT systems for data exchange between the different parties. To improve data exchange, a product-independent process view of the closed-loop supply chain based on the supply chain operations reference model is introduced in this work. Then, an approach is presented to improve data quality in closed-loop supply chain processes through data-based models. The human in-the-loop method is used to capture data and enable integration of this approach in IT systems for closed-loop supply chains. Therefore, a more transparent data flow laying the foundation for improved data quality throughout the supply chain can be achieved.

Keywords: Sustainable Supply Chain, Human-in-the-Loop, Supply Chain Management

Optimizing GHG-Emissions in a Milling Process by Integrating Electricity Mix Data into Manufacturing Parameter Decisions (ID 38)

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Abstract: The industry is responsible for approximately 25 % of global greenhouse gas emissions, contributing substantially to climate change. Sustainable manufacturing has therefore become a significant topic of discussion, resulting in a better understanding of key CO2 emitters in milling processes. This study investigates the potential for optimizing the CO2-eq. emissions of milling processes by considering the composition of the German electricity mix at the time of production. Two scenarios are considered, one with a negligible share of wind and solar energy and one with a dominant share of those energies in the electricity mix. The cradle-to-gate carbon footprints range from 8.44 to 11.91 kg CO2-eq., which corresponds to a 41.18 % increase caused solely by different energy mixes. An optimization of the feed rate based on the composition of the electricity mix during production suggests maximizing the feed rate to shorten production times. Emissions directly attributable to the milling process can be reduced by 11.01 % and 17.60 %, respectively. Expected increase in cost due to increased tool wear were not a part of the investigation. This approach demonstrates the potential for environmentally sustainable manufacturing strategies by integrating electricity mix data into manufacturing parameter decisions.

Keywords: Sustainable machining, CO2 emission, Optimization

Mon, 4th December - 15:30 - 17:00		
Paper Session 7 Sustainable Manufacturing Processes - **Remanufacturing**	**Paper Session 8** Sustainable Materials & Products - **Social Valuation**	**Paper Session 9** Sustainable Manufacturing Systems - **Data & Learning**
Methodology for a holistic analysis and optimization of the circularity of products (ID 76)	Work throughout the industrial revolutions and the impacts of Industry 4.0 on workers (ID 107)	Language Models for Functional Digital Twin of Circular Manufacturing (ID 113)
Simulation of an Integrated Manufacturing Remanufacturing System (ID 50)	The Role of Behavioral and Environmental Economics in Sustainable Manufacturing (ID 79)	Deep Learning-Based Optical Character Recognition for Identifying On-Label Printed Part Numbers of Used Automotive Parts: A Comparative Study of Open Source and Commercial Methods (ID 31)
Elaboration of an Operational Methodology for the Development of a Collaboration Platform for the Reuse of Tools and Tool Components (ID 90)	The Challenges of Entrepreneurship to Low-income People Inclusion in Industry 4.0 (ID 175)	Linking process- and material specific modeling with formalized empirical knowledge in AI approaches for using in resource-oriented decision support systems of production planning. (ID 141)
Developing a novel eco-design tool for disassembling a complex product under uncertainty (ID 40)	Empirical Investigation into the Drivers of Green Manufacturing Technologies (ID 148)	Energy-balanced Job-Shop-Scheduling by G-Code Evaluation with Machine Learning (ID 41)
Enabling Aircraft Recycling through Information Sharing and Digital Assistance Systems (ID 44)	Quantifying the Carbon Footprint of Events: A Life Cycle Assessment-Based Framework for Evaluating Impact of Location and Timing (ID 131)	Towards Sustainable Machining: Synthetic Data Generation for efficient optical Tool Wear Monitoring via Generative Adversarial Networks (ID 110)
Challenges of Automatic Optical Inspection of Used Turbine Blades with Convolutional Neural Networks (ID14)	Digital product passports for light electric vehicles: a tool for reducing environmental impacts, meeting regulatory requirements and implementing a circular economy (ID 206)	Design and Implementation of a Machine Learning System for Crop Monitoring and Irrigation using Internet of Things under Artificial Greenhouse Climatic Conditions (ID 7)

Paper Session 7: Sustainable Manufacturing Processes - Remanufacturing
Mon, 4th December - 15:30 - 17:00, Room 401

Methodology for a holistic analysis and optimization of the circularity of products (ID 76)

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Abstract: Circular economy (CE) is one of the key concepts to improve sustainability through reducing resource dependency and scarcity but increasing resource efficiency. Currently there are no holistic methods to analyze and assess product and material cycles systematically, which would however be a prerequisite to further improve CE. Thus, this contribution presents a methodology for assessing the circularity of products along their whole life cycle. In this way, the greatest potentials for improving circularity can be identified and then iteratively optimized. The methodology is founded on a bottom-up approach and consists of three phases. At the beginning in the data collection phase, all necessary data is gathered and stored in a digital product passport. The key data needed for the assessment are material data (e.g., origin, recycled or primary), energy used, working time from humans and machines, transport routes and involved processes with required tools. In the following evaluation phase, various circularity indicators and a detailed profile of the evaluated product are created. The results are interpreted in the third phase and requirements are derived from the product profile with the indicators to improve the circularity of the product. The methodology is demonstrated on the use case of a spice grinder.

Keywords: circular economy; CE; design for CE; Circularity Assessment; CE Assessment, sustainability; retention option

Simulation of an Integrated Manufacturing Remanufacturing System (ID 50)

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Abstract: In the ongoing European pursuit of a circular economy, remanufacturing has been identified as a crucial strategy for both waste reduction and the attainment of material self-reliance. Remanufacturing offers a promising solution to extend component lifespan and achieve circularity by disassembling, reprocessing, and reassembling returned products to match newly manufactured ones. However, complexities and costs pose significant obstacles, particularly for small and medium-sized enterprises (SMEs), where integrating remanufacturing into existing manufacturing systems can be a solution. The goal of this work is to show how an integrated remanufacturing system can be simulated with conventional software and that the integration could be beneficial for an SME. An approach is suggested and a simulation is conducted on the integration of manufacturing and remanufacturing of water meters. The results of the use case show that for the remanufacturing of water meters, integrating the used products into different points of the manufacturing system could increase the system's output in general.

Keywords: Integrated Remanufacturing, Simulation, Circular Economy

Elaboration of an Operational Methodology for the Development of a Collaboration Platform for the Reuse of Tools and Tool Components (ID 90)

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Abstract: Environmental sustainability is becoming increasingly important for tool and die making companies. Tools and tool components are often discarded because they are no longer needed for their original application, although they are often still good to use. Despite the need for environmental sustainability, the concept of circular economy, especially reuse, is not applied. This paper deals with the elaboration of an operational methodology for the development of a collaboration platform for the reuse of tools and tool components.

The analysis of existing methodologies for the development of collaboration platforms that incorporate environmental sustainability and reuse, shows the need for the development of a specific methodology for tooling. In addition, the market demand for tooling and tool components, the environmental impact of tooling reuse, and potential revenue streams for the platform demonstrate the industry need. The methodology includes a specific approach in each phase and includes determined methods and standards to implement it. Overall, the results of each phase of the developed methodology enable the user to develop a platform with a circular economic and waste reduction orientation. Further research is needed for validation as well as practical implementation and further improvement of the methodology for developing collaborative platforms.

Keywords: reuse platform, tool components, platform economy

Developing a novel eco-design tool for disassembling a complex product under uncertainty (ID 40)

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Abstract. Design for Disassembly (DfD) is a challenging concept that facilitates the disassembly of products for refurbishing and reusing its components. In the context of circular economy, DfD minimizes value loss at the end of product's life and remanufacture costs and maximizes environmental benefits. Therefore, DfD considers technical, environmental financial and social factors, but they are rarely integrated. Today, many studies state that the use of Quality Function Deployment (QFD) approach as a decision support tool helps to make choice by promoting one criterion over one another. However, a systematic approach should also consider uncertainties associated with DfD such as technical characteristics, the recovered parts, the disassembly process, and the optimal disassembly sequence due to the product complexity. The current paper analyzes and compares different QFD approaches in the literature review and then provides a new Fuzzy Sustainable QFD (FS-QFD) methodology, which integrates the three pillars of sustainability. Finally, it shows the effectiveness of the suggested approach through a numerical example.

Keywords: Sustainable QFD, Design for Disassembly, Fuzzy numbers, Decision support tool

Enabling Aircraft Recycling through Information Sharing and Digital Assistance Systems (ID 44)

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Abstract: Due to the environmental targets of the aviation industry, opportunities for optimization are being explored along the entire life cycle of commercial aircraft. Against this background, the recycling of aircraft is increasingly the focus in the aviation industry. Previous research work has therefore examined the overarching recycling process. However, current approaches to improve and increase the aircraft recycling are not sufficient to achieve the defined goals. Based on this motivation, this paper presents first current challenges of aircraft recycling. Subsequently, the paper shows a conceptual framework whose focus is on the lifecycle phases as well as on its stakeholders and its data. Furthermore, a first architecture for the implementation of the approach is introduced. The operationalization in the form of a user interface for a digital assistance system which makes the data available to a recycler in a structured way concludes this paper.

Keywords: End-of-Life, Aviation Industry, Sustainability, Aircraft, Data Sharing

Challenges of Automatic Optical Inspection of Used Turbine Blades with Convolutional Neural Networks (ID14)

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Abstract: This paper presents an automatic optical inspection task for used turbine blades. The defects arising are very small and occur very rarely. The paper analyzes to what extent state of the art deep learning methods of image processing help to solve the inspection tasks. A total of 34 different turbine blades were acquired image-wise for this work. For the localization and classification of the defects, detection methods such as YOLOv7 were used on the one hand, and segmentation methods such as Mask R CNN and QueryInst on the other. Despite a very small amount of data, the methods can be trained to learn the defects and recognize unseen defects. A maximum mAP 0.5 of 60.9 % was achieved. Even though the inspection task was challenging in terms of defect char- acteristics and the number of training data was low, reliable models could be created. The accuracy is not sufficient for full automation, but it can initially generate useful suggestions for the workers and focus attention on critical areas.

Paper Session 8: Sustainable Materials & Products - Social Valuation

Mon, 4th December - 15:30 - 17:00, Room 501

Work throughout the industrial revolutions and the impacts of Industry 4.0 on workers (ID 107)

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Abstract: The concepts of work found in literature distinguish themselves and approach the subject from different perspectives. Aiming to expand and update the reflection on work and its implications for workers, this article presents the main characteristics of human work throughout history from the perspective of industrial revolutions and the potential impacts that the Industry 4.0 paradigm has on it. As critical components of the social sustainability pillar, work and workers must be a focal point in the face of technological changes with potential impacts. To achieve this, impressions of professionals from academic and industrial institutions in Brazil and Germany were collected through self-administered questionnaires and subjected to content analysis. The process highlights impacts ranging from physical aspects of work environments to psychological effects on workers. Ultimately, the article concludes by offering a thoughtful reflection on future guidelines for human work in the context of the new industrial model.

Keywords: Work, Occupational Health and Safety, Working Conditions, Social Sustainability

The Role of Behavioral and Environmental Economics in Sustainable Manufacturing (ID 79)

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Abstract: Sustainable manufacturing is a rapidly growing field that primarily seeks to reduce the environmental impact of manufacturing processes. Although the three-lens approach of social, environmental, and economic aspects remain the primary focus in any sustainability study, the domains of behavioural, and environmental economics along with smart data technologies have not been used in a unified approach. Through a review of the state of the art, this paper establishes the individual cases for each one of these domains and underscores the research interest in their combinatorial application and possible complementary efficacy for advancing the development of sustainable manufacturing strategies. A research agenda involving comparative testing and the development of pertinent policies and interventions for sustainable manufacturing is proposed for the integration of behavioural economics and environmental economics, within the context of sustainable manufacturing.

Keywords: Sustainable Manufacturing, Behavioural Economics, Environmental Economics

The Challenges of Enterpreneurship to Low-income People Inclusion in Industry 4.0 (ID 175)

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Abstract: Industry 4.0 raises concerns about the inclusion of low-income people. Researchers approach entrepreneurship as a path to social inclusion. In this context, this paper aims to investigate how Industry 4.0 engages low-income people under the perspective of entrepreneurship. This paper is based on a systematic literature review using bibliometrics and content analysis. The paper combines RStudio, VOSviewer and NVivo software analysis for conducting a systematic literature review. The paper also conducted a content analysis. This study understands that entrepreneurship has different challenges in Industry 4.0 depending on the social group. To better understand these challenges, low-income people were divided into three social groups: low-literacy and poor people, rural communities and women. The results indicated that the main challenges to engage low-income people on Industry 4.0 are digital inclusion, digital financial inclusion, adoption of digital platforms, and others.

Keywords: Entrepreneurship, Low-income People, Industry 4.0

Empirical Investigation into the Drivers of Green Manufacturing Technologies (ID 148)

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Abstract. Manufacturing industries across the world are employing new cutting-edge techniques referred to as green technologies (GTs) to reduce harmful ecological consequences of production activities. The adoption of GTs is motivated by certain factors, generally termed as drivers. Extant literature identified a variety of drivers and GTs. However, there are very few models that establish the link between them. In spite of indications that drivers can be distinctive to each specific GT of an industry, empirical study on how and to what extent the drivers are influencing the adoption and implementation of GTs, is specifically lacking. Towards bridging these gaps, first, the drivers and GTs are broadly categorized by using extant literature. Subsequently, a theoretical framework is developed based on natural resource-based view (NRBV), which relates the adoption of a specific class of GT to its probable drivers through development of enabling key resources. A case study from an Indian steel manufacturing company is conducted to test the theoretical framework by analyzing the different green initiatives (GIs) implemented by case company. Observed compliances and deviations to the framework are examined. The study provides guidance to manufacturing managers about the selection of appropriate GTs; moreover, this work also contributes insightful information to the body of literature and suggests future lines of inquiry for this area.

Keywords: Green technology, Natural resource based view, Drivers, Key resources, Competencies, Case study

Quantifying the Carbon Footprint of Events: A Life Cycle Assessment-Based Framework for Evaluating Impact of Location and Timing (ID 131)

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Abstract: This research proposes a Life Cycle Assessment-based framework to quantify the carbon footprint of events, considering the event's location and timing. The framework aims to standardise environmental impact calculations through inventory analysis. To validate it, a comparative analysis on conducting an event in different locations and time periods, while maintaining similar scale and nature is conducted. The assessment includes emissions from attendee transport, accommodation, food and drink, and venue. Additionally, it considers emission reductions resulting from attendees not using their personal household resources. This accounts for the actual additional emissions released into the atmosphere as a consequence of the event. The results highlight variations in emissions across different consumption categories based on the selected location and timing. By providing this information, the LCA-based framework provides valuable guidance for event organizers and policymakers to assess event environmental impacts and promote sustainability.

Keywords: Carbon Footprint, Life Cycle Assessment, Events, Quantitative Approach

Paper Session 9: Sustainable Manufacturing Systems - Data & Learning

Mon, 4th December - 15:30 - 17:00, Room 701

Language Models for Functional Digital Twin of Circular Manufacturing (ID 113)

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4 Department of Intelligent Systems, KTH Royal Institute of Technology

Abstract: A key challenge for implementation of a circular economy model in manufacturing systems is the functional dependence of downstream processes on upstream byproducts. Design principles provide a framework for mapping goals to solutions by decomposing complex engineering problems into structured sets of requirements to be satisfied and embodied by design parameters and process variables. Large Language Models can computationally represent such textually-described design elements to quantify interconnections between problems, solutions, and processes. We present a Functional Digital Twin concept, powered by AI language modeling and guided by principles of manufacturing systems design, to identify functionally coupled process variables in an industrial symbiosis and automatically push alerts to stakeholders in a circular manufacturing system. Changes in byproduct composition are pushed downstream, and upstream decision-makers are guided to balance satisfying their design requirements with maintaining circularity of the system. The presented method is demonstrated in a case study of bio-based absorbent materials for intended use in disposable sanitary articles developed from byproducts of the agrofood industry.

Keywords: Language Models, Digital Twin, Industrial Symbiosis, Circular Economy

Deep Learning-Based Optical Character Recognition for Identifying On-Label Printed Part Numbers of Used Automotive Parts: A Comparative Study of Open Source and Commercial Methods (ID 31)

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Abstract: This paper explores the use of deep learning-based optical character recognition (OCR) to identify part numbers for used automotive parts. It compares open source and advanced AI methods to commercial tools from Google, Amazon, and Microsoft. The study finds that fine-tuned open source models outperform commercial services, especially for complex part numbers unrelated to any language structure. The preferred open source method, MaskedTextSpotter, is fine-tuned with image data from old vehicle and electrical parts, captured by a smartphone and 2D barcode scanner. Additionally, a new data augmentation method, CharChan, is introduced, replacing detected characters with random examples for better character recognition. The experiments demonstrate the efficacy of deep learning-based OCR for automotive part number identification.

Keywords: Optical Character Recognition, Circular Economy, Artificial Intelligence, Reverse Logistics

Linking process- and materialspecific modeling with formalized empirical knowledge in AI approaches for using in resource-oriented decision support systems of production planning. (ID 141)

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Abstract: The digitization in the context of the fourth industrial revolution provides new opportunities for the optimal design of production. Data analytics and artificial intelligence become current efforts to integrate in industrial production processes after data availability has been tapped. Energy is increasingly becoming a factor in the resource-oriented management of companies and resource-oriented production planning and control is becoming a survival factor, especially for small and medium-sized enterprises. While CO2 costs become a controlling instrument, historical evaluations are used as a basis for decisionmaking. For energy intensive and hybrid production processes a simulationbased decision support system (DSS) for production planning is validated and further developed for the sand lime brick industry to support the production planning process. The integration of empirical knowledge in the energyintensive control of steam processes, in which quality-critical product parameters are set via thermodynamically complex relationships, is still part of current research approaches. In this paper, an approach for the mapping of an energetic system behavior in the energy-intensive and hybrid production processes will be discussed using the example of sand-lime brick production. In particular, possibilities for using Discrete event simulation (DES) to increase the energy efficiency of steam processes are summarized and linked to formalized empirical knowledge in AI approaches.

Keywords: Decision Support System, Ressource-orientation, sand-lime brick production

Energy-balanced Job-Shop-Scheduling by G-Code Evaluation with Machine Learning (ID 41)

Eddi Miller[1], Anna-Maria Schmitt[1], Tobias Kaupp[1], Rafael Batres[2], Andreas Schiffler[1] and Jan Schmitt[1]

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Abstract: Computerized Numerical Control (CNC) plays an important role in highly autonomous manufacturing systems with multiple machine tools. The necessary Numerical Control (NC) programs to manufacture the parts are mostly written in standardized G-code. An a priori evaluation of the energy demand of CNC-based machine processes opens up the possibility of scheduling multiple jobs according to balanced energy consumption over a production period. Due to this, we present a combined Machine Learning (ML) and Job-Shop-Scheduling (JSS) approach to evaluate G-code for a CNC-milling process with respect to the energy demand of each G-command. The ML model training data are derived by the Latin hypercube sampling (LHS) method facing the main G-code operations G00, G01, and G02. The resulting energy demand for each job enhances a JSS algorithm to smooth the energy demand for multiple jobs, as peak power consumption needs to be avoided due to its expense.

Keywords: CNC, machining, energy consumption, machine learning, design of experiments

Towards Sustainable Machining: Synthetic Data Generation for efficient optical Tool Wear Monitoring via Generative Adversarial Networks (ID 110)

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Abstract: To increase sustainability in the field of machining with regard to energy efficiency improvement and resource conservation, accurate tool wear classification is of a paramount importance. In particular, optical wear monitoring approaches that use artificial intelligence and computer vision techniques have shown enormous potential in the recent past. A critical point to these approaches is the requirement of a lage image dataset of worn tools. The generation of such dataset is associated with a waste of resources, since recording of the data has to be done elaborately during ongoing production and classified by an expert. In this paper, the possibilities of generating synthetic training images with the help of generative adversarial networks (GANs) were investigated. A limited set of images was acquired for training GANs which then were used to increase the number of images for the training of our tool wear classificator. The approach enables a resource-efficient approach for the training process such that the accuracy and robustness of tool wear classification systems through the use of GANs can be ensured.

Keywords: Generative Adversarial Networks, Machine Sustainability, Tool Wear, Condition Monitoring

Design and Implementation of a Machine Learning System for Crop Monitoring and Irrigation using Internet of Things under Artificial Greenhouse Climatic Conditions (ID 7)

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Abstract: More than 50 % of the world's freshwater supplies are consumed by agriculture and due to the rapid increase in the food demand due to population increase the demand for freshwater is increasing. Due to the increased pressure on the water resource there is an urgent need to come up with advanced technologies that will enable conservative use of water during the irrigation process. Intelligent irrigation systems are now replacing the conventional manual irrigation process which was based on physical soil water measurement. The researcher brings into life a new web based implementation of the modern application of Internet of Things (IoT), microcontroller based embedded systems and machine learning algorithm in a greenhouse environment. This intelligent greenhouse system was designed through the use of an ESP8266 microcontroller, different electrical and environmental sensors such as the humidity sensor, soil moisture sensor, pumps etc. Crops will not be just irrigated for the sake of irrigation but will be irrigated when irrigation is highly required depending on the current state of the greenhouse soil condition. For this to be achieved different parameters about the greenhouse soil environment are monitored by the sensing nodes which consist different sensors and logged into the databases in the cloud within which our Soil Condition Classification Neural Network SCCNN is deployed and trained to predict the current soil condition in the greenhouse/ farm such that the farmer can set the irrigation times appropriately. The data

collected by the sensor nodes and the real-time predictions of the soil condition are displayed on the Web application dashboard in real time.

Keywords: Internet of Things, Soil Condition Classification Neural Network

Tue, 5th December - 11:00 - 12:30		
Paper Session 10 Sustainable Manufacturing Processes - **Education**	**Paper Session 11** Sustainable Materials & Products - **Technical Processes I**	**Paper Session 12** Crosscutting Topics in Sustainable Manufacturing - **Business Models & Regional Integration I**
Work Engineering for Sustainability: Required Education in Engineering (ID 105)	Frontloading Approach for Energy Efficiency in Forming Technology (ID 179)	Olive Sector Integrated Artificial Intelligence and Modern Technologies Model for Palestine (ID 20)
Concept of an integrated information and education platform for sustainable development (ID 71)	Multi-stage and -technology paper forming for sustainable packaging (ID 43)	Business Model Design in context of Circular Economy (ID 34)
Innovating Blended Learning Model for Professional Education in Manufacturing (ID 91)	Real-time information system for improved efficiency in the broaching of aero-engine components through edge computing and data analysis (ID 126)	From talk to action: a diagnosis of sustainable logistics practices in LATAM, a collaborative study between industry and academia. (ID 192)
Bridging the educational gap in circular design and engineering – a concept and case from Austria (ID 28)	Residual stresses generation in two-stage rotary swaging of tubes (ID 33)	Ecosystem collaboration for sustainability: Learnings from the food system (ID 24)
	Method to simulate the dynamic behaviour of micro ball end mills (ID 53)	Urban agrifood circularity: exploring consumable and capital micro circular production loops (ID 22)

Paper Session 10: Sustainable Manufacturing Processes - Education

Tue, 5th December - 11:00 - 12:30, Room 401

Work Engineering for Sustainability: Required Education in Engineering (ID 105)

Sandra F. B. Gemma[1], Daniel Braatz[2],
Raoni Rocha[3] and Flavia T. de Lima[4]

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Abstract: Recent research shows that there is a significant lack of disciplines related to the field we are referring to as 'work engineering' in undergraduate engineering courses in Brazil. The organization of work and the challenges imposed by production models directly impact the health and safety of workers and indirectly affect society. It is argued that ergonomics, as a scientific discipline and professional practice, can serve as a means for engineering to analyze and understand the variability present in the occupational environment. The objective here is to discuss work from a critical perspective and its central role in society and the constitution of health, aiming to position it as a protagonist in the education of engineers, as well as to debate the need for the integration of different fields and knowledge proposed by 'work engineering'. Lastly, the importance of designing work situations within the context of engineering will be discussed, highlighting how it can be a vector for transforming productive situations, allowing for safe, healthy, and efficient environments. In this sense, the expanded concept of 'work engineering' can contribute to social sustainability, laying the groundwork for the construction of more dignified human relations and work environments (SDG8, UN Agenda 2030).

Keywords: work, health, safety, ergonomics, design

Concept of an integrated information and education platform for sustainable development (ID 71)

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Abstract: To meet the growing demand for sustainable products, companies are increasingly striving to manufacture products aligned with the United Nations' (UN) 17 Sustainable Development Goals (SDGs). To communicate this sustainability to customers, companies often use sustainability seals to ensure that the environmental, social and economic impacts during production meet certain criteria. However, the increasing number of these seals awarded by independent organizations often creates confusion rather than clarity due to the lack of transparent criteria and award procedures. Consequently, these seals overlap the usefulness which creates an ambiguity in the consumer's mind while making a purchase.

This paper introduces the concept of an information platform, which provides consumers with information about product sustainability, considering the entire product lifecycle (PLC). It aims to

collect and evaluate data from different product groups to enable consumers to make purchasing decisions based on their criteria and values.

Research was conducted to assess consumers' access to consolidated information on sustainable product development and manufacturing. The identified gap led to the presentation of the multi-level model of the digital platform. The concept benefits consumers, companies and society by facilitating information and education about sustainability aspects distinguishing companies from the competition in the production of consumer-oriented and sustainable products.

Keywords: sustainable products, product lifecycle, sustainable manufacturing, digital platform, 17 SDGs

Innovating Blended Learning Model for Professional Education in Manufacturing (ID 91)

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Abstract: Advancements in technology and the increasing prevalence of digitalization in industry require a new approach to professional education. The primary objective is to enhance the skills of working professionals, ensure content is relevant to industry needs, increase learner engagement, and optimize learner and instructor efficiency. To achieve these goals, a new methodology is proposed, utilizing constructive alignment, outcome-based education, and blended learning strategies. This approach incorporates asynchronous digital learning, synchronous online lectures, and interactive debriefing sessions, providing an engaging blend of self-paced learning and active, instructor-led experiences. Evaluation results show an improved course structure and a positive learning experience, despite initial implementation challenges. While not exclusively designed for sustainable manufacturing education, this approach offers innovative learning pathways and has the flexibility to integrate specific modules, such as those related to sustainability. Based on evaluation feedback and measurable learner outcomes, ongoing refinements to this model suggest a promising shift in the approach to professional education within the manufacturing sector.

Keywords: Blended Learning, Professional Education, Manufacturing, Sustainability

Bridging the educational gap in circular design and engineering – a concept and case from Austria (ID 28)

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Abstract: Despite promising developments towards a circular economy, a recent study by EUROSTAT concluded that only 12% of EU's economy is circular. One cause is suspected in particular in the fact that the scientific knowledge relating to the design and development of sustainable and recyclable products and processes has not arrived sufficiently in industrial practice. Educational offers for practitioners in circular design and engineering are still sparse and are taken up hesitantly by companies in this context either. To close this educational gap, we have developed a particular training program for education in Circular Design and Engineering principles. The development of the program was publicly funded and involved five industry partners from furniture and interiors industry. In this

paper, we describe the underlying educational concept and lessons learned from a particular application of the concept in the Austrian furniture and interiors industry.

Keywords: Circular Economy, Circular Engineering, Engineering Education

Paper Session 11: Sustainable Materials & Products - Technical Processes I

Tue, 5th December - 11:00 - 12:30, Room 501

Frontloading Approach for Energy Efficiency in Forming Technology (ID 179)

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Abstract: The early stages of forming process development offer a high degree of design freedom and therefore cost advantages in implementing energy efficiency measures. However, this potential often remains unused in industrial applications due to the lack of a cost-efficient and simple approach.

This frontloading approach addresses the specifics of forming process d316

evelopment in existing production environments and bridges the gap between new development and retrofitting in SMEs. Four steps from analysis to modelling and measures to implementation provide an easy-to-follow guidance. Key challenges in data collection and uncertainty management are addressed.

Using two forming processes as examples (bulk and sheet metal forming), a reduction in total energy consumption is achieved while the productivity remains unchanged. Therefore, the proposed frontloading approach opens up new opportunities for energy efficiency in forming technology.

Keywords: energy efficiency method, forming technology, frontloading

Multi-stage and -technology paper forming for sustainable packaging (ID 43)

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Abstract: Forming of paperboard enables great design freedom, high productivity and sustainable packaging solutions. The limiting factor in forming processes is the low ductility of the natural fiber material. This does not only often lead to unwanted cracks, but also to an insufficient control of wrinkle formation. Compared to packaging manufactured from plastics, visual deficiencies have been unavoidable so far. In order to extend the process limits and enhance the product optics, two-stage processes as well as the combination of different forming methods are promising process routes and therefore discussed in this paper. So far, research in paperboard forming has mainly focused on forming with rigid tools. Recently, forming with active-media is gaining interest. Investigations of process combinations of active-media based forming followed by deep drawing show that both maximum forming depth as well as the wrinkle compression are enhanced. In order to explain the findings scientifically and to develop a numerical model, the materials used have been characterized. Subsequent investigations were carried out numerically and validated experimentally using optical analysis methods. The findings open up new approaches in design and process planning for sustainable, formed packaging.

Keywords: Paper-forming, multi-stage-process, media-based forming

Feasibility analysis of carbide broaching tools in the machining of Inconel 718 (ID 126)

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Abstract: Cutting fluids used in machining have received a lot of attention due to their adverse environmental and economic effects. Researchers have studied cutting fluid usage in traditional machining processes such as turning, facing, milling, etc. However, few studies focused on the cutting fluid used in band sawing applications. This study reports a literature review of the usage of the cutting fluid in band sawing and their sustainable and economic aspects. A review of the literature and industrial data has shown that the majority of band saw blades use high-speed steel as the cutting tool material for cutting metal. This study presents a metric-based sustainability assessment and a detailed analysis of recent economic factors such as the cost of the cutting fluids used in band sawing through industrial case studies. A global survey of the cutting fluid usage in the bandsawing application has shown that the majority of the industry is employing flood coolant application. The flood coolant application cost can be as high as 8% of the total consumables cost of the band sawing process.

Keywords: Band Sawing, Sustainability, Cutting Fluid

Residual stresses generation in two-stage rotary swaging of tubes (ID 33)

Lasse Langstädtler[1,2,3], Kasra Moazzez[1,3], Dhia Charni[4], Christian Schenck[1,2,3], Jeremy Epp[2,4] and Bernd Kuhfuss[1,2,3]

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Abstract: Forming operations are usually divided in consecutive stages that result in the desired part geometry. These stages are designed by considering the mass distribution and are strictly bound to process and machine demands. On the other hand, the mechanical part properties can be sensitive to the forming sequence. Hence, the sequence can be optimized to improve part properties.
Forming induced residual stresses give the potential to improve the service properties which are dependant on the whole material flow history along the production line. A better knowledge of the generation of residual stresses leads to a more sustainable manufacturing process. Furthermore, hollow parts offer reduced weight thus saving energy and material consumption especially in the transportation sector. Thus, a sustainable swaging process needs to be designed with the understanding of multi-critical effects and interactions.
In this study, the diameter reduction of annealed E355 steel tubes by infeed rotary swaging was exemplarily investigated. The reduction was performed by three different routes — one stage, two stages and three stages swaging using several swaging dies to reduce a diameter from 20 mm to 8 mm. The resulting residual stresses and geometric properties were discussed. It could be observed that an increased number of forming stages contributed to improved part properties like better surface quality and compressive residual stresses. Furthermore, the integration of multiple forming stages in a new swaging die design was presented. The improved part properties and new die design enhanced the processes and parts sustainablity.

Keywords: Free forming, Rotary swaging, Residual stresses

Method to simulate the dynamic behaviour of micro ball end mills (ID 53)

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Abstract: Instable process behaviour is one of the biggest challenges in micromilling and has a significant impact on tool wear. This leads to reduced workpiece quality and higher scrap. Therefore, it increases the resource and energy consumption. This paper presents a new simulation method and uses the example of a micro ball end mill for machining X37CrMoV5-1 to show how tool deflection and process forces can be determined as a function of individual process parameters and how optimal process kinematics can be achieved. For this purpose, the individual modelling steps are presented and it is explicitly shown how the necessary characteristic values for the simulation can be determined experimentally.

Keywords: micro milling, process stability, energy efficiency

Sustainable Cutting Fluid Usage in Bandsawing of Additively Manufactured 316L Stainless Steel: Surface Integrity Evaluation (ID 133)

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2 Institute for Sustainable Manufacturing, University of Kentucky, Lexington, USA
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Abstract: Metal additive manufacturing (MAM) components often require postprocessing for end applications. Bandsawing is an alternative process established in industry to remove parts from the build plate in wire arc additive manufacturing (WAAM). The removal of WAAM components from the build plate by bandsawing shows high potential, especially in the sustainable manufacturing of large-scale MAM parts. This work aims to study the influence of cooling conditions on the surface integrity of band sawed WAAM and conventionally manufactured 316L stainless steel. Sustainable cutting fluid strategies could impact surface integrity and their effectiveness in bandsawing MAM parts. The investigated cooling strategies are compressed air, minimum quantity cooling (MQC), and flood cooling. The surface integrity metrics of the band-sawed surfaces have been evaluated. The work aims to gain a deeper understanding of bandsawing AM components for industrial applications. Overall, the sustainable cutting fluid solution, MQC, has a similar effect on the surface roughness, microstructure, and cutting forces, compared to flood cooling

Keywords: Additive manufacturing, Sawing, Sustainable cutting fluid, WAAM

Paper Session 12: Crosscutting Topics in Sustainable Manufacturing - Business Models & Regional Integration I

Tue, 5th December - 11:00 - 12:30, Room 701

Olive Sector Integrated Artificial Intelligence and Modern Technologies Model for Palestine (ID 20)

Ahmed Abu Hanieh and Afif Akel Hasan

Birzeit University, Al Marj street 1, Birzeit P.O.Box 14, Palestine

Abstract: Olive sector in Palestine suffers from serious problems starting from cultivation process passing through oil extraction process ending with final products treatment. Most of the processes are old traditional ones and lacking modern technologies. The main focus of this paper is to put forward a roadmap for implementing artificial intelligence and modern technological components in olive sector processes suitable in Palestine. Most of olive trees are planted on hilly terrains hence precludes using heavy duty mechanical instruments for harvesting, and requiring the use of light weight hand-held harvesting tools. Soil moisture and nutrition elements can be determined through sensors to optimize irrigation and fertilizers addition. Harvesting can be well planned based on olive fruits readiness by measuring oil content and quality. The final produced virgin oil can be turned to extra virgin oil by implementing further treatment processes where modern technologies are implemented. Replacing the conventional olive plant with automated one shows economic benefits with less than 2 years payback period, as well environmental by 11% and 20% energy and water consumption reductions respectively. Modern technologies can also be integrated in post processes of olive sector like touristic wood works, soap manufacturing, and other oil-based food products.

Keywords: Olive sector, Artificial Intelligence, Modern Technologies, Olive oil, Supply chain, Food technologies

Business Model Design in context of Circular Economy (ID 34)

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Abstract: In dynamic environments, businesses not only look for sustainable technology solutions, but also for new business model opportunities that management can apply as they move to a more sustainable future. Being embedded in the process of analyzing the status quo and identifying potential improvements of sustainability management, this article focuses on the development of a catalog with circular economy-based business model patterns to provide an overview of universally applicable implementation measures for business model development. For this purpose, four steps were conducted: An extensive literature research to identify a comprehensive collection of sustainable business model patterns with specific emphasis on circular economy, reduction of identified patterns to exclude redundancies and ambiguities, derivation of the influence of these patterns on the elements of the Business Model Canvas – taking into account their impact on environmental sustainability –, and a final enrichment with further details for practical application. This includes a definition, benefits, barriers, implementation steps as well as filterable categories for the specific selection of business

model patterns. The result is a catalog which provides a valuable resource for businesses looking to adopt more sustainable business practices.

Keywords: circular economy, sustainability, biological transformation, bioinspiration, catalog, business models, business model patterns, business model canvas

From talk to action: a diagnosis of sustainable logistics practices in LATAM, a collaborative study between industry and academia. (ID 192)

Teresa Brandi[1], Heidi Romero[2], Agatha Clarice da Silva-Ovando[3], M. Ileana Ruiz-Cantisani[4], Jocabed Becerra Soliz[3] , and Leonardo Fuentes Pereira[3]

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Abstract: Supply chains are estimated to produce more than 50% of the world`s CO2 (World Economic Forum, 2020). As climate change becomes more evident, raising awareness about sustainable supply chains is becoming a priority. This study focuses on the survey results on sustainable supply chains conducted in 2022 through a collaboration between universities in Latin America. More than a dozen universities collected a sample of over 400 surveys across ten countries. We applied the Partial Least Squares (PLS) regression model to respond to how the combination of a set of drivers and the characteristics of a company influence the level of commitment to sustainability, measured in terms of their existing measures, practices, and policies. As a result, we identified the level of understanding of sustainability for companies of different sizes and sectors and the drivers of businesses to design, implement, and control the outcomes of sustainable practices in their operations.

Keywords: Sustainability, Sustainable logistics, Sustainability drivers, Latin America

Ecosystem collaboration for sustainability: Learnings from the food system (ID 24)

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Abstract: Individual firm and ecosystem level efforts are required to meaningfully improve sustainability across the food system. While there has been extensive research on collaboration for sustainability in the food system, these studies focus on working along the supply chain. As the food system is complex with relations and effects spanning across supply chains and industries, another approach is for firms to look beyond their traditional supply chain to tackle sustainability at their ecosystem level. In this regard, there is a need to investigate how firms collaborate with partners to influence sustainability in their ecosystem. In this paper, we present findings of an exploratory study with interviews of 17 firms across the food system that work with partners in their ecosystem for sustainability. We found that informal collaboration among partners is common but occur differently at certain stages of innovation and development and happens even when sharing of benefits are not yet agreed upon. The findings suggest how individual firms can support ecosystem change and how they can work with partners to develop and propagate innovative sustainability solutions in the food system.

Keywords: sustainability, ecosystem, collaboration

Urban agrifood circularity: exploring consumable and capital micro circular production loops (ID 22)

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Abstract: The circular economy concept is typically applied at scale, especially for high value products and materials. The dominant manufacturing model is for large global factories with research and practice independent of agriculture. This paper challenges the dominant “big is beautiful” ethos and explores how agricultural and industrial production can operate at local, urban scale with wastes circulating for consumable and capital production. The research case is a UK city where food wastes could be used for food production and beverage production waste could be used to produce building materials. The research explores the industrial symbiosis engineering challenge of small-scale waste conversion and the digital challenge of identifying and measuring waste flows for conversion. In considering waste conversions through local, distributed manufacture this paper also tackles the digital challenge of how to source local, small volume material flow data for optimization. Future potential research avenues of micro manufacture as well as digital twins are discussed.

Keywords: circular economy, urban manufacturing, distributed manufacturing, industrial symbiosis, digital

Tue, 5th December - 13:30 - 15:00		
Paper Session 13 Sustainable Manufacturing Processes - **Student Session**	**Paper Session 14** Sustainable Materials & Products - **Technical Processes II**	**Paper Session 15** Crosscutting Topics in Sustainable Manufacturing - **Business Models & Regional Integration II**
Towards sustainable consumer electronics products: Development of a user-friendly digital product passport for the electronics sector (ID 147)	Machining cycle detection based expert system for improving energy efficiency in manufacturing (ID 75)	Towards circular business models in the punching industry: Leveraging smart sensor technology for sustainable manufacturing processes (ID 102)
Project Alternative Powertrains Simulator (Hybrid)	Fluid-Structure Interaction Between Chip And Metalworking Fluid In Sawing (ID 69)	The Essential Role of Hydrogen Certification in Positioning Argentina in the Global Green Hydrogen market (ID 203)
Towards a circular economy: Obtaining high-value products from fishing industry waste	Initial study on milling in an ultrasonically excited metalworking fluid bath (ID 56)	Pilot projects for lower carbon emissions in Argentine steel manufacturing industry (ID 180)
Improving Adoption of Clean Cooking Technologies amongst beneficiaries at Base of Economic Pyramid	Polycrystalline diamond tool for resource efficient milling of granite (ID 36)	Challenges of Manufacturing Low-Carbon Transformation and Research on the Construction of China's Green Manufacturing System (ID 130)
Green Hydrogen for Domestic Cooking in Ghana (ID 112)	Twist drill point geometry to minimize specific cutting energy. Experimental and FEM simulation (ID 177)	Aligning strategic priorities in manufacturing and sustainable operational practices in firms: exploration and evidence in North-East Colombia (ID 8)
	Eco-sustainable improvement of super duplex stainless steel turning trough CryMQL technique (ID 67)	Risk assessment for small businesses in South Africa: A focus on Soweto (ID 155)

Paper Session 13: Sustainable Manufacturing Processes - Student Session

Tue, 5th December - 13:30 - 15:00, Room 401

Towards sustainable consumer electronics products: Development of a user-friendly digital product passport for the electronics sector (ID 147)

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Abstract: The linear economy's limitations, characterized by excessive consumption and waste generation, necessitate a shift toward sustainable practices. The digital product passport (DPP) serves as a repository of product-specific information throughout the entire lifecycle, offering transparency and knowledge crucial for the transition toward a circular economy (CE). The paper reviews existing DPPs and identifies their gaps which point to the lack of a clearly defined framework for their development. A framework for developing an effective DPP that addresses the limitations of the current DPPs is proposed. The framework includes defining clear objectives, identifying relevant information, establishing an adaptable interface, and ensuring secure data-sharing systems. A case study is presented, demonstrating the practical application of the proposed framework in the consumer electronics sector. A prototype DPP for a Logitech G502 gaming mouse is developed, showcasing its potential to empower consumers in making informed decisions and addressing the critical issue of electronic waste generation. The paper concludes by discussing the challenges identified during the case study and directions for future work.

Keywords: Digital Product Passport; Circular Economy; E-waste

Project Alternative Powertrains Simulator (Hybrid)

Adharsh Suresh Kumar, Roopchand Babu, Raunak Pravin Chepurwar, Ahad Memon, Shweta Vijay Gandhe, Xijing Cui, Onkar Rohidas Phadke,

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Abstract: -

Keywords: -

Towards a circular economy: Obtaining high-value products from fishing industry waste

Agustín Brandoni Rodriguez Vannini; Martín Ojeda Henriquez; Juan Blas Peredo Camio; Lucas Franzi; Mateo López Gaffney

Instituto tecnológico Buenos Aires (ITBA), Argentina

Abstract: Chitosan is a well-known biopolymer chemically obtained from naturally occurring chitin, which is, after cellulose, the second most abundant natural polymer in the world. Despite the widespread occurrence of this polysaccharide, the main sources of chitin have been crabs and shrimp shells which are currently waste materials of the food processing and fishing industries. The utilization of these waste materials represents a remarkable prospect for industrial development and, at the same time, a solution to the environmental problem they generate. In this context, chitosan was used

to prepare high-value products for the biomedical and environmental sanitation fields. In particular, the preparation of antimicrobial wound dressing as well as efficient adsorbents for water treatment will be described.

Keywords: -

Improving Adoption of Clean Cooking Technologies amongst beneficiaries at Base of Economic Pyramid

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Abstract: -

Keywords: -

Green Hydrogen for Domestic Cooking in Ghana (ID 112)

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Abstract: Green Hydrogen could be used as a sustainable cooking fuel, especially in countries of the global south in which cooking with carbon-based, or biomass fuels is prevalent. This paper presents a criteria based assessment of the sustainability of cooking with hydrogen in comparison to charcoal and liquefied petroleum gas. The research methodology adopts a systematic literature review to provide a comprehensive overview of the research. Based on this, a morphological analysis is conducted to display possible hydrogen cooking scenarios. A chosen hydrogen scenario is then subjected to a sustainability assessment and compared with the aforementioned conventional cooking methods. The findings of this paper reveal that while hydrogen presents itself as a potential alternative, it is currently not a more sustainable option. Despite its lower climate change impact when compared to liquefied petroleum gas and charcoal, hydrogen falls short in several other sustainability aspects, such as investment costs, marine and freshwater eutrophication or safety concerns related to the usage of the energy source.

Keywords: Green Hydrogen, Cooking, Sustainability Assessment

Paper Session 14: Sustainable Materials & Products - Technical Processes II

Tue, 5th December - 13:30 - 15:00, Room 501

Machining cycle detection based expert system for improving energy efficiency in manufacturing (ID 75)

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Abstract: The transformation of manufacturing companies towards a carbon-neutral economy requires energy transparency, energy analyses and the implementation of energy efficiency measures. Given the continuing skills shortage, the need for automated analysis methods to gain insights from measurement data is increasing. Expert systems that combine the knowledge of multiple experts, analyze load profiles, and derive energy efficiency measures are one approach to tackle this challenge. This paper presents an expert system that quantifies energy efficiency potentials based on the detection of machining cycles and derives promising measures. For this purpose, a new algorithm for the detection of machining cycles is introduced, which shows an accuracy between 76.7 % and 94.3 % on a representative production day for electrical load profiles of different types of production machines. Since the detected machining cycles are in a form impractical for further processing, information is extracted as energy performance indicators. The expert system utilizes this aggregated information to identify energetic hotspots and derive appropriate energy efficiency measures. The machining cycle detection based expert system is demonstrated on a typical production chain for the metalworking industry within the ETA research factory at the Technical University of Darmstadt.

Keywords: Pattern Recognition, Energy Analysis, Sustainable Manufacturing

Improving chip curling with reduced amount of cutting fluid in circular sawing with internal coolant supply (ID 69)

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Abstract: Circular sawing is an important intermediate step in industrial production. Due to the increasing demand for high-performance materials such as titanium alloys, efficient manufacturing for such difficult-to-machine materials is becoming more and more important. Traditionally, large quantities of cutting fluid are supplied to the sawing process by means of flood lubrication. However, the application of cutting fluids is expensive and energy-intensive. Additionally, cutting fluids pollute the environment and are harmful to health. The aim should therefore be to develop resource-saving machining processes and to reduce the need for cutting fluids in a sustainable manner. During sawing, a saw kerf is created which makes it difficult to supply the cutting process with cutting fluid. Chip formation plays an important role in the circular sawing process. This paper shows that by using a transparent kerf, the chip deformation can be studied and evaluated using a high-speed camera. By investigating the chip diameter from the camera recordings, the filling of the saw tooth gullet can be evaluated. As main result of the investigation an internal coolant supply in circular sawing can reduce the volume flow by 50 % and improve the chip deformation process at the same time. This allows a sustainable and resource-efficient design of sawing processes.

Keywords: Chip curling, Cooling, Efficiency

Initial study on milling in an ultrasonically excited metalworking fluid bath (ID 56)

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Abstract: Energy and resource efficiency are seen as key drivers of the industrial transformation towards a low carbon economy. In particular, machine tools, which are essential to value creation, have a significant share of industrial greenhouse gas emissions due to their high-energy consumption. The energy demand for the provision and supply of metalworking fluids (MWF) alone can account for up to 25 % of the total energy demand. The aim of this study is to investigate and fundamentally design an alternative cooling lubricant concept. This concept does not require continuous pumping of the coolant supply. Instead, the milling operation takes place in an immersion bath filled with metalworking fluid. An additional ultrasonic (US) actuator causes the coolant to vibrate, allowing the coolant to penetrate deeper into the cutting zone. The machining tests include a comparison of classic flood cooling, immersion bath milling and immersion bath milling with US stimulation. To compare the processes, the flank wear, the workpiece surface roughness and the bending moments due to the cutting forces were analyzed. The energy assessment allows a final evaluation of the processes.

Keywords: Milling, energy efficiency, immersion bath, ultrasonic

Polycrystalline diamond tool for resource efficient milling of granite (ID 36)

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Abstract: State of the art in tooling for cutting granites are sintered grinding tools having synthetic diamond grains bound together in metal matrix usually a cobalt copper alloy. Routers for CNC machining of stone plates come in various forms such as face milling tools, finger bits, edge profiling tools etc. and have either segmented or continuous grit. Characteristic of the grinding processes the material removal rates are relatively slow and inefficient compared to geometrically defined tools such as the ones used for milling metals or wood. In this study, a milling tool having four polycrystalline diamond inserts vacuum brazed to the tool body have been used to machine Nero Assoluto Granite. The edges of the cutting inserts were laser ablated using ultrashort pulsed lasers to form round and chamfer micro-geometries. Wet milling of granite plates was carried out at constant cutting and feed speed to study the effect of various edge geometries on the tool wear as well as cutting forces. The results showed that the cutting edges with laser ablated chamfer resulted in the least amount of tool wear as well as the lowest average cutting force and therefor make a decisive contribution to energy and resource efficient machining processes.

Keywords: milling of granite; tool development; PCD tools

Effects of Drill Point Geometry on Cutting Forces and Torque when Drilling AA1050 (ID 177)

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Abstract: Reducing energy consumption in drilling operations is crucial for achieving sustainability goals. A study examined 36 drill bits with different geometries and conditions on AA1050. It assessed thrust forces and torque in two machining conditions (Cmin and Cmax) while considering mesh density, tool geometry, and boundary conditions. The results show that finer mesh models exhibit lower thrust forces, while mass scaling primarily influences torque. The pilot hole configuration decreases force, consistent with experiments. Torque decreases by increasing mesh density, matching with the experimental results. Finally, temperature and chip shape are mesh-dependent, affecting torque and force. As a result, our FEM model effectively predicted thrust force and torque, emphasizing the role of the pilot hole configuration in temperature and plastic strain results.

Keywords: Twist drill, Point geometry, Cutting forces, Computer simulation, Pilot hole

Eco-sustainable improvement of super duplex stainless steel turning trough CryMQL technique (ID 67)

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Abstract: In machining processes, the environmental footprint reduction is a fact that is been addressed in recent years. In this line, the use of recycled CO2 as cryogenic cutting fluid in those processes is taking advantage in comparison with other lubricooling alternatives to replace oil emulsions in workshops. This technique is characterized by its high cooling capability and its cleaning efficiency. Besides, it is environmentally innocuous due to the CO2 is captured from a primary process to be used as cutting fluid. However, the CO2 has low lubricant properties what implies a challenge to be used in heat-resistant alloys because combines both high hardness and low thermal conductivity. Therefore, in this work is explored the use of CO2 combined with biodegradable oil spray under the CryoMQL technique for dealing with super duplex stainless steel during turning operations. In particular, the CryoMQL technology was optimized for achieving a successful process through tool life improvement. The results show that the optimization carried out implies that the use of the CryoMQL technique extends tool life a 45% in comparison with the use of conventional oil emulsions, obtaining in this way not only an environmental improvement but also a technical one in this kind of alloys.

Keywords: CryoMQL, Eco-sustainable machining, Difficult to cut alloy

Paper Session 15: Crosscutting Topics in Sustainable Manufacturing - Business Models & Regional Integration II

Tue, 5th December - 13:30 - 15:00, Room 701

Towards circular business models in the punching industry: Leveraging smart sensor technology for sustainable manufacturing processes (ID 102)

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Abstract: The punching industry (PI) remains largely dependent on unsustainable resource use in its manufacturing process, consuming finite materials. Evolving market needs for increased environmental sustainability in the PI causes punching companies to reevaluate their existing manufacturing processes. Considering this trend, this research explores the prerequisites for transitioning to circular business models (CBMs), a subset of sustainable business models, by using smart sensor technology (SST) supporting a sustainable manufacturing process (SMP). Prior research has shown that using different sensors pertaining punching tools and machines is prevalent. Standard parts in the punching tool itself address these challenges of an imprecise set-up of the punching tool on the punching machine resulting in process improvements and efficiency enhancements. Yet, no similar data-driven punching tool concepts have been installed highlighting the novelty. To address this gap, this study examines how data can be gathered and successfully utilized to support SMP fostering CBMs in the PI based on data-driven punching tools. Mixed methods are applied in a practice-oriented project, involving a Swiss-based manufacturer. The results demonstrate several key drivers supporting SMPs enabled by data-driven punching tools. Future research should involve a larger number of interviews and further field testing to increase maturing SST data-driven punching tool.

Keywords: Punching industry, punching tool, smart sensor technology, circular business model, sustainable manufacturing process

The Essential Role of Hydrogen Certification in Positioning Argentina in the Global Green Hydrogen market (ID 203)

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Abstract: This study explores the fundamental role of Hydrogen in the energy transition and the need for a certified, regulated, and cost-effective Hydrogen market. Emphasis is placed on the role of Hydrogen certification as a tool to verify its renewable origin, an essential factor for stakeholders in energy production and distribution. The focus is on how Argentina can take advantage of its potential as an important Hydrogen producer for European markets. Existing Hydrogen certification schemes and ongoing projects in Argentina and Europe are analyzed.

Keywords: Certification, Sustainable Energy, Hydrogen, developing country

Pilot projects for lower carbon emissions in Argentine steel manufacturing industry (ID 180)

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Abstract: To reach climate policy objectives, it is imperative to achieve zero emissions across all production activities, including the traditionally hard-to-abate steelmaking sector. This entails implementing fundamental technology and process changes, as well as reducing material demand and increasing recycling efforts. Presently, the steelmaking process emits substantial CO2 during heating and production. A promising solution lies in the introduction of low carbon hydrogen (H2) into the steelmaking process, thereby yielding nearly zero-emission steel. Although this approach may not be economically viable today, projections for 2050 indicate promising developments in electrolysers technology, reduced costs of electricity from renewable energy sources (RES), and the implementation of CO2 carbon taxes, significantly enhancing the economic feasibility of low carbon steel production. Argentina presents a unique advantage in this endeavor, being both a substantial producer and exporter of steel, and endowed with abundant high-quality renewable resources and promising reserves of Natural Gas (NG). Given this potential, pilot projects are crucial to demonstrate the industrial viability of low carbon steel production in the country.

Keywords: Industry 4.0, Craftsmanship, Cell Production, Lean Manufacturing, Intangible Assets

Challenges of Low-Carbon Transition of Manufacturing Industry in Developing Countries and Research on the Construction of Green Manufacturing System in China (ID 130)

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Frida Li [b], Xinyi Tong [b], Jerome Feldman [b]

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Abstract: Resource and environmental issues are common challenges faced by mankind, and it is a common choice for global economies to promote green growth and implement a new green deal. Based on the current situation that developing countries are in the stage of high input, high consumption and high emission development, this paper analyzes the challenges of resource and energy efficiency, technology, and environmental impacts, and takes China as an example to study and analyze the background of the establishment of the green manufacturing system, the overall strategic framework and implementation strategy, as well as the effectiveness of the current stage. This can provide a reference model for industrial green low-carbon transition and sustainable manufacturing.

Keywords: Manufacturing, Production, Sustainable development, Management, Environment

Aligning strategic priorities in manufacturing and sustainable operational practices in firms: exploration and evidence in North-East Colombia (ID 8)

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Abstract: Recently, issues such as global warming and ecosystem deterioration have demanded corporate actions towards a responsible orientation to operations. Particularly, manufacturing firms

can exhibit such a responsible orientation through the implementation of sustainable operational practices (SOP). Such practices can also pave the way to consolidate the different strategic priorities in manufacturing (SPM) that drive business value. Based on a sample of 412 manufacturing firms in Bucaramanga, Colombia, the purpose of this study is to characterize different portfolios of SOP as well as profiles of firms based on their SPM. Results evidence three forms of SOP, related to: (i) product design and transformation, (ii) supply chain, and (iii) reverse logistics. Furthermore, sampled firms exhibit four main SPM: (i) natural environment and social responsibility, (ii) flexibility, (iii) innovation and efficiency, and (iv) quality and customer satisfaction. Results show that there are remarkable differences regarding SOP related to product design and transformation as well as supply chain across profiles of SPM. Notwithstanding, the extent of implementation of reverse logistics takes place regardless of their SPM. The study contributes to an increased understanding of how firms adopt a more responsible behavior. Furthermore, the study provides evidence concerning the articulation of such organizational response and the priorities to capture value in manufacturing.

Keywords: Virtual reality, work integrated learning, human centered design, immersive virtual work integrated learning, higher education institutions

Risk assessment for small manufacturing businesses in Soweto (ID 155)

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Abstract: A risk assessment is tool that assists businesses to identify, analyse and evaluate various types of risks that their severity. The manufacturing sector serves as the backbone of the social and economic development in South African, Soweto. Risks assessments have been conducted in various sectors but not the Soweto manufacturing businesses. It is therefore imperative that this study focuses on this very important sector to assist it in being sustainable. A risk assessment was conducted for 120 manufacturing businesses in Soweto. The study identified 5 types of risks namely the financial, operational, business, legal and third-party risk. The businesses were categorised based on the outcome of the production, and a risk rating tool was used to analyse and evaluate the level of risks that exists. The risk rating tool categorised the risks in terms of low-risk, medium-risk, and high-risk. The tools' outcome was the total risk type per manufacturing business type and the risk values per risk type. The study found that financial risk is a predominant risk that affects all the manufacturing businesses that were engaged, and that food, glass, textile, and wood manufacturers are the businesses impacted most.

Keywords: Risk Assessment, Manufacturing businesses, Risk rating

Tue, 5th December- 15:30 - 17:00		
Paper Session 16 Sustainable Manufacturing Processes - **Student Session II**	**Paper Session 17** Sustainable Materials & Products - **Technical Processes III**	**Paper Session 18** Sustainable Manufacturing Systems - **Factory Planning & Production Management I**
Gamification as a learning tool to promote sustainability issues for societal challenges	Trends and resource-efficient application of solid end mills in plastics machining: a comparative m1arket study (ID 30)	Sustainable Manufacturing for SMEs: An agile readiness model of decarbonization by combining theory and practice (ID 84)
Spaceship Earth: An Educational Game on Sustainable Manufacturing (ID 197)	Comparison of an additive with a subtractive method from the perspective of sustainability (ID 183)	Planning and Control of Value Creation Networks in Timber Construction (ID 200)
Circular economy approach for developing countries through the up-cycling of PET bottles and the use of additive manufacturing countries through the up-cycling of PET bottles and the use of additive manufacturing	Sustainable dry turning of aluminum alloys using pulsed high-pressure cryogenic jet cooling (ID 58)	Towards Real-Time Condition Monitoring of Electroplating Plants (ID 164)
Use of shallow geothermal source for heat provision to future ITBA building	Impact of Modified Clamping System on Rotary Swaging Workpiece Quality (ID 88)	Planning multimodel assembly lines like multiproduct pipelines (ID 94)
An Approach to Quantifying the Lifecycle Sustainability Impacts of Tungsten Carbide Tools (ID 150)	Hybrid polishing tool for internal finishing of complex part interiors in magnetic abrasive finishing (ID 96)	System Boundaries, Data Sources and Assessment Methods in the Ecological Evaluation of Complex Assembly Products (ID 100)

Paper Session 16: Sustainable Manufacturing Processes - Student Session II

Tue, 5th December- 15:30 - 17:00, Room 401

Gamification as a learning tool to promote sustainability issues for societal challenges

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Abstract: Gamification is a methodology to transform activities, systems, services, products, or organisational structures into experiences based on games [1, 2]. Gamification is also closely related to digitalisation and entrepreneurial activities because games can be developed in virtual environments or by game boards. Besides, they have a large market. Gamification is also a relevant research topic that is attracting the attention of academic scientists, and this trend is demonstrated by the number of publications that have been vastly increasing in the last few years.

All the members of the consortium of the Erasmus+ project entitled “Digital skills and cross-domain entrepreneurship for societal challenges” proposed to a group of selected students to develop their skills and competencies related to digital tools and entrepreneurial approaches. During a dedicated workshop, twenty-three students of different nationalities and backgrounds were divided into four groups. All the groups were assigned to a task based on the development of a prototypal game concerning sustainability and societal challenges. Four games have been developed based on different mechanics, systems and equipment (gameboard, pieces, dice, etc.). They have been tested, and we believe this approach and these implementations can contribute to diffusing sustainability awareness and its relationship with societal challenges.

Keywords: Sustainability, Societal Challenges, Entrepreneurial Competencies, Digital Competencies

Spaceship Earth: An Educational Game on Sustainable Manufacturing (ID 197)

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Abstract: Developing an educational game about sustainable manufacturing can be an effective way to teach people about the importance of sustainable practices in the manufacturing industry. Through educational sustainable manufacturing games, users can learn about the impact of sustainable manufacturing on the environment, along with strategies and techniques that can be used to reduce waste and methods of sustainable production. A minimal number of articles have focused on board game development for sustainable manufacturing, and of the few, most focused on educational simulation of machines/systems, catering to a specific profession. This paper chronicles the creation of "Spaceship Earth," a sustainable manufacturing board game from game design to testing. It explores the entire process of developing an educational game, from game theory to final testing. The game incorporates various elements such as resource management, decision-making, and problem-solving to simulate the real-world challenges faced by manufacturers when implementing sustainable practices. By examining the design of educational games, this paper aims to gain insight into the constraints of engineering education gamification. The paper demonstrates the potential of educational games as a means of promoting sustainability and provides a useful framework for designing and developing similar games in the future.

Keywords: Sustainability assessment, Life cycle assessment, Aerospace manufacturing

Circular economy approach for developing countries through the up-cycling of PET bottles and the use of additive manufacturing countries through the up-cycling of PET bottles and the use of additive manufacturing

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Abstract: -

Keywords: -

Use of shallow geothermal source for heat provision to future ITBA building

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Abstract: Low enthalpy geothermal heat is often not considered. This job studies the feasibility of an efficient thermal installation to supply shallow geothermal heat to factories, buildings, farms, or similar. - Key objectives are: replacement of conventional energy sources (fossil fuel, electricity), reduction of GHG emissions, carbon credits and project profitability. – As study case, the use of shallow geothermal heat is analysed for the envisaged future ITBA building.

Keywords: Energy and resource efficiency, CO2 neutral production, Sustainable energy transition, Sustainable energy development

An Approach to Quantifying the Lifecycle Sustainability Impacts of Tungsten Carbide Tools (ID 150)

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Abstract: Tungsten carbide cutting tools are widely used for their high machining performance and low cost. However, their cost does not currently reflect the material rarity, environmental costs, nor societal costs associated with their production. Critically, embodied energy makes a sizeable contribution to the total lifecycle energy consumption. This study quantifies the true triple bottom line cost of the tools with respect to established sustainability metrics by leveraging cross-disciplinary insights from the product, process, and system levels. Based on the adjusted cost, a comparative analysis of the cutting tool sustainability on the profitability of a nickel-based superalloy machining process was carried out for different tools. Tool wear rates were experimentally measured across a range of industrial feeds and speeds for milling of Inconel 718. Using a Taylorian cost optimization model, the relative influence of the true cost of different tungsten carbide tools was compared. In all cases considered, changes in tool cost had a minimal impact on process profitability, suggesting that more sustainably produced cutting tools may readily justify increased tooling costs. Thus, identification and further development of more sustainable cutting tools may offer a meaningful opportunity to enhance sustainability performance of tungsten carbide cutting tools enabling more sustainable manufacturing.

Keywords: Tungsten carbide, embodied energy, cutting tool, tool cost, sustainable manufacturing, machining

Paper Session 17: Sustainable Materials & Products - Technical Processes III

Tue, 5th December- 15:30 - 17:00, Room 501

Trends and resource-efficient application of solid end mills in plastics machining: a comparative market study (ID 30)

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Abstract: Due to their high share of value creation in manufacturing, the influence of machining processes and the therein applied cutting tools on profitability and sustainability is often high. Plastics machining differs significantly from metal machining and requires special tools or machining strategies. However, innovation and research usually address the area of metal machining, while plastics machining is often based on in-house experience and the use of tools that were originally developed for metal machining. Thus, potentials regarding energy and resource efficiency of those cutting processes often remain unused. This paper analyses the market situation and needs for required innovations of companies in the plastics machining industry. Therefore, a market study was conducted in which both tool manufacturers and users were asked about relevant aspects regarding the production and application of tools as well as assessments of trends and desired innovations. The results help to identify future research needs so that potentials in the area of plastics machining can be raised with regard to energy and resource efficiency. An important finding of the study is that both tool manufacturers and users see a need for vibration-damped tools and for a wider range of tools with more special tools for plastics machining.

Keywords: milling, plastics machining, market study

Comparison of an additive with a subtractive method from the perspective of sustainability (ID 183)

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Abstract: Additive Manufacturing (AM) is increasingly used for the manufacture of parts in different industrial sectors and, therefore, it becomes relevant to evaluate the mechanical performance that can be achieved with this process and the possible impacts on the environment compared to traditional processes.

In this paper, two alternative production methods for fabricating a standard stainless steel tensile specimen are compared: Selective Laser Melting (SLM) and machining. Functional tests were carried out until the fracture of the pieces. The amount of material used was measured. In addition, the energy consumed to produce the pieces was estimated. Both production processes were compared concerning the measured tensile properties, material consumption, and additional data from the literature. The results obtained from generative design and topological optimization of a part are discussed, as well as the implications regarding the sustainability of the processes.

Keywords: Selective Laser Melting, Machining, Generative Design, Sustainability

Sustainable dry turning of aluminum alloys using pulsed high-pressure cryogenic jet cooling (ID 58)

Jan Harald Selzam, Niklas Enslein, Daniel Gross and Nico Hanenkamp

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Abstract: As well as producing contamination-free parts, dry machining is a sustainable alternative to conventional machining processes using metalworking fluids. Despite these benefits, chip breaking and chip removal are challenges in dry machining processes, particularly when turning ductile materials, which are known for continuous chip formation and therefore long chips. Due to their tendency to become entangled around machine components, these chips have to be removed manually, posing a risk to productivity and operator health.

Recent studies have demonstrated the effectiveness of pulsed high-pressure emulsion cooling for chip breaking. This paper aims to transfer these findings to sustainable dry machining and investigates the influence of pulsed high-pressure cryogenic jet cooling on chip breaking and chip removal. Therefore, liquid CO_2 at pressures up to 200 bar is used as a cooling medium in turning processes of two aluminum alloys and is applied continuously or pulsed to the machining area. It has been shown that high-pressure cryogenic jet cooling improves chip breaking and chip removal, allowing a wider range of cutting parameters, widening the process window and providing a higher level of sustainability, productivity and safety in dry machining.

Keywords: Sustainable machining, Pulsed high-pressure cryogenic jet cooling, Dry turning, Aluminum, Carbon dioxide

Impact of Modified Clamping System on Rotary Swaging Workpiece Surface Quality and Sustainability (ID 88)

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Abstract: Rotary swaging is a sustainable cold forming process that reduces the radius of axis-symmetrical workpieces. The clamping system is a critical part of this process that affects the behavior of the workpiece during the process. The dynamic characteristics of the clamping-workpiece system can affect the process dynamics, such as vibrations in the whole structure, dynamic forces and contact time between the tools and the workpiece, and angular displacement of the workpiece. This research aims to modify the dynamics of the process by changing the contact characteristics between the clamping system and the workpiece. Instead of using a quasi-rigid clamping head, an elastic rubber spacer was tested as a spring-damper element. The study evaluated the impact of this clamping-workpiece system modification on the sustainability of the rotary swaging process in different aspects and surface quality of the final product via roundness and cylindricity measurements. The results could lead to parts that require less post-processing and are closer to a ready-to-use state, depending on the desired application.

Keywords: Sustainability, Modified clamping, surface quality.

Hybrid polishing tool for internal finishing of complex part interiors in magnetic abrasive finishing (ID 96)

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Abstract: This paper describes the development of a new hybrid polishing tool, which consists of magnetic particles and a water-soluble binder and transforms from a bonded-tool phase to a particle-brush phase during polishing. During the bonded-tool phase, the binder remains intact, and material is removed from the peaks of the target surface where abrasive is pressed against the surface. Once the binder dissolves in the lubricant, the magnetic particles separate, form a brush tool (particle-brush phase), and polish the surface while conforming to the surface geometry. The phase transition timing is determined by the lubricant type. The magnetic particles can be collected using magnetic force and reused; the hybrid tool thus contributes to resource utilization and waste reduction. The effects of tool geometry, tool binder content, and lubricant type on the tool-phase transformation and polishing characteristics are clarified by applying the new hybrid tool to internal finishing of stainless steel tubes, made using directed energy deposition, using magnetic abrasive finishing (MAF). MAF mechanically removes material by the action of abrasives pressed against a workpiece with magnetic tools suspended in a magnetic field. Compared with conventional MAF, the hybrid tool achieves a target surface finish with significantly less material removal, minimizing waste production.

Keywords: Magnetic Abrasive Finishing, Directed Energy Deposition, Reusable Polishing Tool

Paper Session 18: Sustainable Manufacturing Systems - Factory Planning & Production Management I

Tue, 5th December- 15:30 - 17:00, Room 701

Sustainable Manufacturing for SMEs: An agile readiness model of decarbonization by combining theory and practice (ID 84)

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Abstract: Decarbonization is a critical area as companies work to meet the environmental mandates associated with their environmental, social, and governance (ESG) commitments. It provides significant potentials for the sustainable manufacturing of Small and medium-sized enterprises (SMEs) to match the demands from the downstream value chain. However, SMEs find themselves not ready to take the first step due to a lack of sufficient professional resources. This paper presents a literature review and practical investigation to find out the root causes of decarbonization issues with regard to SMEs. As novel countermeasure, an agile readiness model with consideration of production and environment engineering is developed which allows collectively identifying the current status and targeted performance. Finally, the proposed approach is validated through a case study with industrial partners (in developed countries like Germany and The Netherlands, and emerging countries like China).

Keywords: Sustainable Manufacturing Systems, Decarbonization, Readiness Model, Assessment Tool.

Planning and Control of Value Creation Networks in Timber Construction (ID 200)

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Abstract: Almost 40 percent of the global carbon emissions are caused by the construction and building sector. Additionally, the production of traditional building materials like concrete and steel requires a large amount of energy. The demand for residential buildings is increasing none the less and can potentially be met by utilizing more sustainable materials like timber in construction. However, timber construction is still connected to a rather manual value creation chain and analog information transfer. To make the process more time- and energy efficient, this paper proposes a framework for the value creation system of urban timber construction from the forest to the city. The three-leveled framework, based on the principles of Industry 4.0, connects the urban development planning with the vertical networking of digital technologies and the horizontal networking in the value chain. The framework is implemented to a dashboard using Microsoft Power BI to demonstrate the close relations of the layers.

Keywords: Value Creation Network, Timber Construction, Digital Transformation

Towards Real-Time Condition Monitoring of Electroplating Plants (ID 164)

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Abstract: For securing a high-quality plating process, one of the main challenges in electroplating is the dosing of electrolytes. The optimal dosing and the related demand for resources do not only influence the coating quality but can also have a high environmental and economic relevance. Currently, the condition monitoring approaches related to dosing are mostly model-based and are seldom real-time capable. Therefore, a concept for real-time data-based condition monitoring of electrolytes is proposed. The paper discusses the challenges of pre-processing and modeling time series data with machine learning algorithms and quality requirements and availability of data within the electroplating process. Moreover, the usage of neural networks for condition monitoring of time series data is presented and discussed in a case study with a focus on anomaly detection. With this example, the applicability of a data-based approach for dynamic prediction of electrolyte chemicals is presented and evaluated.

Keywords: Condition Monitoring, Data Mining, ANN, Electroplating, Electrolytes, Chemicals, Real-Time

Planning multiproduct assembly lines through a continuous-time model accounting for carbon footprint (ID 94)

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Abstract: This work presents an efficient mathematical formulation for the optimal planning of multiproduct assembly lines. The aim is to establish a cyclic production agenda that minimizes the sum of inventory holding and transition costs per unit time. Besides, carbon footprint of assembled products is tracked along the line while optimally determining task times and operating modes. Batch sizing and sequencing in synchronous assembly lines have been typically addressed through discrete-time approaches that imply significant computational burden. In contrast, our novel representation resembles continuous-time pipeline scheduling models that permit to obtain optimal solutions in reasonable times. Results show the capabilities of the optimization approach to solve large instances of the problem, also demonstrating how task times and operating modes can be handled to reduce carbon footprint with no loss of productivity.

Keywords: Assembly lines, Sequencing, Batch sizing, Optimization

System Boundaries, Data Sources and Assessment Methods in the Ecological Evaluation of Complex Assembly Products (ID 100)

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Abstract: Life Cycle Assessment (LCA) has become the most popular method for assessing the environmental impact of products. It is internationally standardized by ISO 14040 and ISO 14044, which outline the general methodology, steps, and issues to be considered. While the standards ensure a consistent general understanding of the method, it does not provide explicit recommendations on the decisions to be made when conducting an LCA. These decisions include, in particular, the definition of system boundaries, the prioritization of data sources, and the selection of appropriate assessment

methods. For some industries, particularly raw materials and process goods, the gap has mostly been filled by industry standards. The vast number of manufactured goods that are the result of complex assemblies originating from multi-tiered supply chains still lack such industry standards. This work addresses the issue by conducting a thorough literature review on the subject. As a result of the literature review, methodological gaps are identified and quasi-standards are derived from previous studies, thus providing general guidance for future LCA of complex assembly products.

Wed, 6th December - 11:00 - 12:30		
Paper Session 19 Sustainable Manufacturing Processes - **Repair and Maintenance**	**Paper Session 20** Sustainable Materials & Products - **Additive Manufacturing**	**Paper Session 21** Sustainable Manufacturing Systems - **Factory Planning & Production Management II**
Approach for structured repairability assessment for automated repair processes (ID 176)	A proposal for an extension of the Consumption Performance Sustainability Index to machining processes (ID 29)	Corporate climate protection measures to improve the carbon footprint in production (ID 9)
Development of a Maintenance Framework for addressing Power Outage in South Africa (ID 168)	In-Process Detection of Defects on Parts Produced by Laser Metal Deposition Using Off-Axis Optical Monitoring (ID 207)	Optimal design of pipeline networks for inter-plant water and energy integration (ID 140)
Boosting resource efficiency and circular economy of the manufacturing companies in Finland (ID 12)	Scoping review of directed energy deposition in the production of functionally graded materials (ID 178)	Technologies and concepts for material recirculation in Urban Secondary Raw Material Factories (ID 83)
Development and Implementation of Reliability Centered Maintenance Framework in Large Organisations (ID 167)	Investigations on the use of photodiodes for in-situ defect detection in laser-based powder bed fusion of metals (ID 184)	Integrated analysis: A concept of smart manufacturing systems adoption (ID 191)
	Dexel-Based Temperature Prediction for Wire-Arc Additive Manufacturing Toolpath Optimization (ID 47)	Sovereign services for machine tool components for resource-efficient machining processes (ID 137)

Paper Session 19: Sustainable Manufacturing Processes - Repair and Maintenance

Wed, 6th December - 11:00 - 12:30, Room 401

Approach for structured repairability assessment for automated repair processes (ID 176)

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Abstract: Repair is a crucial process to recover resources and reduce waste within a circular economy. Automating manual and laborious repair processes has the potential to establish greater economization and efficiency. While research on assessing product repairability exists, there is currently limited research specifically focused on the repairability regarding automated processes. Therefore, this paper investigates the existing knowledge on automation, manual and automated repair processes from theory as well as practical applications, to identify benchmarks for reparability assessment for automated processes. Based on these requirements, solutions, processes, and operating resources are identified. A standardized and structured approach for evaluating the repairability of products for automated repair is proposed. This research also highlights the economic and ecological advantages, as well as the sustainability challenges and potentials of using automated repair processes. Overall, this research contributes to the development of a more sustainable and efficient CE through the advancement of automated repair processes.

Keywords: Repair, Repairability Assessment, Automated repair

Development of a Maintenance Framework for addressing Power Outage in South Africa (ID 168)

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2 Achievers University, Owo, Nigeria.
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Abstract: In recent times, South Africa has been experiencing power outages, which has significant effect on businesses and economic wellbeing of the nation. To address this challenge, this study develops a maintenance framework that power-generating industries in South Africa can implement. Primary data was collected from company X that is a major subsidiary of the power generating industry in South Africa to probe the root causes of power outages in recent times. The analysis of the data obtained was carried out using Pareto chart. The results obtained identified delay in maintenance operations as one of the possible causes of power outages. The rework job was observed to be tardy by 50 days. This length of days is critical enough to cause power outage. To address this, a framework was developed to assist in effective scheduling of maintenance activities. Hence, this work provides an insight into the possible causes of power outages in South Africa and how they can be mitigated to avoid load shedding.
Keywords: Maintenance framework, Load shedding, Power outage, Pareto chart

Boosting resource efficiency and circular economy of the manufacturing companies in Finland (ID 12)

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Abstract: Increased resource efficiency and circular economy among manufacturing industry could help to turn sustainability into economic value while simultaneously supporting policy objectives set to decrease CO2 emissions. Overall, this will require changes in organizational strategies, fast uptake of new technologies and skilled workforce. The paper investigates the status of the Finnish manufacturing industry in the uptake of both practices in product design and production, development and future needs in resource efficiency and circular economy in terms of research, skills and investments. A total of 38 Finnish manufacturing companies (18 small and medium size enterprises) answered the survey. The results show that overall Finnish industry considers that the uptake of resource efficiency and circular economy is in at a good level. However, respondents were able to identify several enablers and barriers that could further facilitate the transition towards sustainable manufacturing. Finally, the paper investigates collaboration needs of the manufacturing companies with research organisations and universities in several different sustainable manufacturing technologies such as material efficiency. In the discussion part a collaboration model between a Finnish university and regional manufacturing industry companies is represented and regional testbeds supporting twin transition will be discussed in detail.

Keywords: Business strategies, Industry 5.0, Circular Economy

Development and Implementation of Reliability Centered Maintenance Framework in Large Organisations (ID 167)

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Abstract: Large organisations across the world constantly seek to ensure the optimal operation of their processes in order to remain competitive against their industry peers. This study seeks to help the organisation improve maintenance performance by developing a framework that can be adopted by the organisation in implementing Reliability Centered Maintenance (RCM). This study develops a model to help companies to adopt RCM and to do that, a questionnaire and a company were selected to test the model. A questionnaire was sent to a selected population to gather the views of people regarding maintenance within the selected organisation. This is achieved by first investigating the current maintenance regime in Company Y via a survey. Historical data relating to maintenance were obtained and analysed to highlight problem areas. Plant documents relating to maintenance policies were sought for the understanding of the status quo. The results obtained indicate that from 2016 to 2021, the organisation did not meet the maintenance target of 95% and there are major maintenance issues, which have affected the equipment availability and organisation's productivity. Thus, a guideline for the implementation of Reliability Centered Maintenance was developed for use. The guideline will be useful for organisations in their quest to achieve Reliability Centered Maintenance for optimal productivity.

Keywords: *Maintenance, Optimal operation, Productivity, Reliability Centered Maintenance*

Paper Session 20: Sustainable Materials & Products - Additive Manufacturing

Wed, 6th December - 11:00 - 12:30, Room 501

A proposal for an extension of the Consumption Performance Sustainability Index to machining processes (ID 29)

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Abstract: We previously proposed a Consumption Performance Sustainability Index to assess the sustainability of additive manufacturing products made by Fused Filament Fabrication. For simplicity and to get broader applications, the index was defined as dimensionless and composed of several factors related to the manufacturing process. The index included material and energy consumption and the performance of the transformed material, in the last case measured as the yield or the maximum resistance of the produced part, in comparison with the characteristics of the feedstock material. The index can highlight the most sustainable among other solutions based on different print orientations and part densities. We now propose extending the Consumption Performance Sustainability Index's validity to additive manufacturing and Computerized Numerical Control (CNC) machining processes. For this purpose, each factor has been revised and, if necessary, expanded to include process parameters of machining processes. A new organization of all the factors has been introduced based on groups of parameters related to material properties and usage, part design, consumed energy, and machine time. Case studies have been investigated to evaluate preliminarily this new index for assessing product sustainability.

Keywords: Additive Manufacturing, Subtractive Manufacturing, Polymers, Sustainable Manufacturing, Consumption Performance Sustainability Index

In-Process Detection of Defects on Parts Produced by Laser Metal Deposition Using Off-Axis Optical Monitoring (ID 207)

Marco MAZZARISI[1], Maria Grazia GUERRA[1], Marco LATTE[1], Fabrizia DEVITO[1,2], Luigi Maria GALANTUCCI[1], Sabina Luisa CAMPANELLI[1], Fulvio LAVECCHIA[1], and Michele DASSISTI[1]

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Abstract: Laser Metal Deposition (LMD) is emerging among metal Additive Manufacturing technologies because of the wide variety of applications in which it can be employed. This technique is an evolution of laser cladding, which is used nowadays for the fabrication and repair of complex metal components, promoting the sustainability of manufacturing. One of the main drawbacks hindering the widespread use of these technology is the complexity of implementing monitoring equipment on industrial LMD systems with limited modification options. Therefore, it is essential to develop appropriate off-axis systems that allow effective monitoring of the deposition process. The present work proposes a prototype off-axis monitoring system consisting of a pair of specially set cameras capable of analyzing the evolution of the melt pool and discerning fundamental information on geometry, size and brightness intensity. By relating this information with the process outcome, it could be possible to forecast the most frequent defects related to the deposition process.

Experimental tests have been carried out in which powder flow and laser alterations were specifically induced. The prototype system enabled the characterization of each type of process variation and the determination of specific indicators, to be set as basis for achieving a zero-waste sustainable manufacturing process.

Keywords: Additive manufacturing; Laser Metal Deposition; Sustainability; Process monitoring, Defect detection

Directed Energy Deposition of Functionally Graded Materials: Towards Resource- and Cost-Effective Manufacturing (ID 178)

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Abstract: This paper presents an overview of the production of functionally graded materials (FGMs) using directed energy deposition (DED) where the advancements, challenges, and future directions in this field are explored. Functionally graded materials entail the joining of two or more different materials to produce a part of which the chemical and thus mechanical properties vary along one or more dimensions of a part. This study explored the benefits of FGMs, including enhanced multifunctionality, weight optimization and reduced cost. Additive manufacturing (AM), particularly DED, has emerged as a promising technique for fabricating complex FGM structures. By utilizing FGMs, designers can overcome the limitations imposed by expensive materials when developing critical components. Through strategic engineering, the material composition of the part can be tailored as a gradient between expensive materials and more affordable alternatives in non-critical regions. This approach optimizes costs while ensuring performance requirements are met. It is also widely acknowledged that utilizing AM techniques in place of or in addition to conventional manufacturing techniques can decrease material waste. The reduced material waste and enhanced resource utilization offered by DED make it a good solution for sustainable manufacturing. Furthermore, by harnessing the potential of FGMs and DED, industries could unlock new design possibilities, improve product performance, and achieve greater manufacturing efficiency.

Keywords: Directed energy deposition, functionally graded materials, waste reduction, resource efficiency, sustainable manufacturing

Investigations on the use of photodiodes for in-situ defect detection in laser-based powder bed fusion of metals (ID 184)

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Abstract: The sustainability of AM is strongly related to the ability of producing functional parts using minimal resources. In-situ monitoring saves energy and material by providing information to support

process stops in case of anomalous events detected in critical regions. In this work, AlSi10Mg samples with different defect conditions were PBF-LB/M manufactured under the observation of photodiodes in three wavelength ranges. The samples were scanned through synchrotron-based micro-CT, and a defect score was attributed to every point in a non-destructive manner. The results were registered to the emissions acquired during the PBF-LB/M process. An exploratory data analysis has shown that the mean and standard deviation of the emissions of defect points do not differ from the ones found for points labelled as normal by micro-CT. A neural network was trained to infer the points' quality based on their emissions. The maximum F1-score was 4.79 %, suggesting that the photodiodes in the studied set-up are not suitable for the in-situ identification of local porosities in PBF-LB/M parts.

Keywords: *Additive Manufacturing (AM), Laser-based Powder Bed Fusion of Metals (PBF-LB/M), Process Monitoring, Computed Tomography (CT)*

Dexel-Based Temperature Prediction for Wire-Arc Additive Manufacturing Toolpath Optimization (ID 47)

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Abstract: Wire-Arc Additive Manufacturing (WAAM) has been established as a new technology for industrial use-cases such as low-lot size manufacturing or part repair services. A key aspect when developing such WAAM processes is thermal management during the layer-by-layer metal deposition. To maintain a stable welding process in-depth knowledge about the heat distribution is required. Thus, predicting the heat flux for a given part geometry already in the process development stage using Computer-Aided-Manufacturing Systems (CAM) would be beneficial. However, current state-of-the-art approaches are computationally expensive and time intensive. Therefore, they are hardly applicable for WAAM applications. In this paper, a dexel-based metal cutting and deposition simulation is combined with a temperature prediction model, which is integrated in the toolpath planning algorithm when defining a build-up strategy for a given part geometry. The approach is based on a temperature prediction algorithm, that calculates temperature fields for deposited material volume considering basic material properties. Calculated temperature fields can be utilized for optimizing the welding toolpath to achieve stable process conditions across the global part geometry. The approach is demonstrated for a part geometry in the laboratory of TU Wien, utilizing a 6-axis welding robot and a CMT welding power source.

Keywords: Wire-Arc Additive Manufacturing, Toolpath Planning, Temperature Simulation, Computer-Aided-Manufacturing

Paper Session 21: Sustainable Manufacturing Systems - Factory Planning & Production Management II

Wed, 6th December - 11:00 - 12:30, Room 701

Corporate climate protection measures to improve the carbon footprint in production (ID 9)

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Abstract: . Individual climate protection measures are already being successfully implemented by many companies. But often, there is a lack of comprehensive information for selecting and implementing the right measures that fit the individual company's emissions profile. This paper presents the systematic development of a toolbox of climate protection actions for small and medium-sized enterprises in order to reduce greenhouse gas emissions. The development process followed a four-step methodological approach: conducting intensive research on climate protection measures in applied and practical literature, reducing and grouping the measures into their corresponding emission categories, structuring and categorizing the measures into specific types of areas, and providing detailed profiles and descriptions of each measure. The resulting list of climate protection actions follows underlying basic principles (i.e. improvement of the emission factor, reduction of emission-generating activities and behavioral changes) which allow an individual derivation of measures. In its final version, the toolbox provides small and medium-sized enterprises with a comprehensive and accessible resource for identifying and implementing effective climate protection actions according to their emissions profile.

Keywords: climate protection management, toolbox, climate protection measures, SMEs

Optimal design of pipeline networks for inter-plant water and energy integration (ID 140)

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Abstract: The concentration of specific industries in relatively small areas exists in many countries. This characteristic incentivizes cooperation and facilitates the optimal use of common resources. An example of this is the cluster of crop and chemical manufacturing industries in the south of the Santa Fe province in Argentina, next to the Parana River. All of these plants are closely linked to the use of water streams in associated processes. The objective of this work is to minimize the overall costs of water and energy consumption through the optimal design of an inter-plant pipeline network. This is achieved by considering the daily availability and demand of hot water at each node over time, while ensuring that all pipelines are capable of reversing flows, if needed, at the expense of specific equipment and operating costs. The optimization model developed in this work can be categorized as a mixed-integer linear programming formulation that considers fluid dynamics variables, temperatures, distances, energy and flow balances in order to properly determine the required

pipeline diameters. The construction and operation of water pipelines in concentrated industrial regions can leverage positive impacts on the sustainable use of natural resources. In contrast to previous contributions, explicit consideration of flow reversals offers benefits that can significantly reduce investment costs.

Keywords: Holistic Production System, Biological Transformation, Literature review

Technologies and concepts for material recirculation in Urban Secondary Raw Material Factories (ID 83)

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Abstract: Supply chains for cities are currently challenged due to geopolitical conflicts and general resource scarcity of substantial raw materials. One currently discussed strategy to reduce the dependency of external supply is a relocalization of production facilities to cities enabling local secondary raw material extraction integrated in Circular Economy value creation chains. Urban regions offer the potential for the installation of circular and secondary raw material factories because of the concentration of waste- and byproducts, which can reduce transport efforts. The installation of urban factories is however highly dependent on the economic feasibility as well as the acceptance of the local environment. One critical source for the retrieval of critical raw materials are e-wastes. The current retrieval of these critical raw materials from e-wastes is connected to high spatial requirements and production volumes. These characteristics would hamper an installation in urban areas. Current literature provides different approaches with the intention to adapt e-waste treatment to these special conditions. To assess which of these are suitable for utilization in urban environments, this paper provides an analysis of their possibility to generate an *urban fit*. To do so, criteria containing ecologic, social, and economic, technological indicators are defined and an assessment of the suitability is conducted.

Keywords: Urban manufacturing, secondary raw materials, reverse production technology, urban metabolism, urban mining

Integrated analysis: A concept of smart manufacturing systems adoption (ID 191)

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Abstract: Recent advancements in manufacturing systems, such as advanced embedded sensing, big data analytics, Internet of Things (IoT) and robotics amongst others, are promising paradigm shifts in the manufacturing industry towards smart ecosystems. The traditional centralised and hierarchical structures have been criticised for being too rigid and inflexible to meet the demands of modern industry. Research gaps exist in terms of how to evaluate and predict production system performance in order to facilitate rapid decision making and production control. An integrated analytical approach methodology to solve practical manufacturing problems is imperative. Thus, this study presents the

integrated analysis of smart manufacturing systems. Furthermore, this study established an evaluation framework to configure the smart manufacturing system based on system formulation, conceptual model and model configuration. The smart enabled manufacturing technologies were showcased, with data analytics serving a major function showcasing the remaining useful life (RUL) of the study case component. Smart manufacturing involves using cutting-edge manufacturing production models and digital technology to realise a vision for resource utilisation in response to production of high-quality products.

Keywords: Smart manufacturing, integrated analysis, industry 4.0

Sovereign services for machine tool components for resource-efficient machining processes (ID 137)

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Abstract: The increasing use of modern edge computing solutions in production is creating new opportunities for collecting and processing internal machine data. This data provides information on the load on a machine tool during operation. Using the technical expertise of component manufacturers, specific loads on individual components can be derived. This knowledge provides valuable insights for machine and component manufacturers to analyze the usage behavior of machine operators and use it for sustainable product development. Additionally, this information can be used to implement new business models, creating financial incentives for sustainable usage through load-oriented payment models. As a result, new potentials for users in efficient design and optimization of manufacturing processes arise. Data and service ecosystems play a crucial role in this context by establishing the technical framework that enables sovereign data exchange and the deployment of expert knowledge in the form of digital services. Therefore, this paper demonstrates a concept and the potential for sustainable machining based on digital services for two central components of a machine tool, the spindle and the feed axis.

Keywords: Machine tool, Sustainable machining, Digital manufacturing system

Tenaris

COMPANY PROFILE

TenarisSiderca

Industrial Excellence from Argentina to the World

Since the installation of our industrial plant for the production of seamless steel tubes in 1954, we have been a key player in the oil and gas market in Argentina, expanding globally over the years.

Our factory has state-of-the-art technology, aimed at reducing the environmental impact of operations.

We accompany leading companies in facing the challenges of the most demanding environments around the world.

8,300
Employees

1,300,000 tons
Annual production capacity

70% of the production
exported to 18

- Located in Campana, Province of Buenos Aires
- 1 Research and Development Center recognized locally and internationally.
- 1 Corporate University
- It contributes with its products and experience to the development of **Vaca Muerta**, the country's energy engine.

Integrated Manufacturing System

- 1 steelworks
- 2 hot rolling mills
- 1 Premium accessory plant 1
- coupling factory
- 1 cold drawing plant 1
- protectors' plant

Strategic location on the most important route in the country, with access to the river-sea through its own port, and internal connection with the railroad tracks to directly reach Vaca Muerta.

Products and Services

Casing, drilling, production, and conduction pipes with different steel grades. Corrosion resistant, high temperatures and high collapse. Premium connections. Dopeless® technology and Rig DirectTM service that offer operational, well productivity, health, safety, and environmental benefits.

Main markets

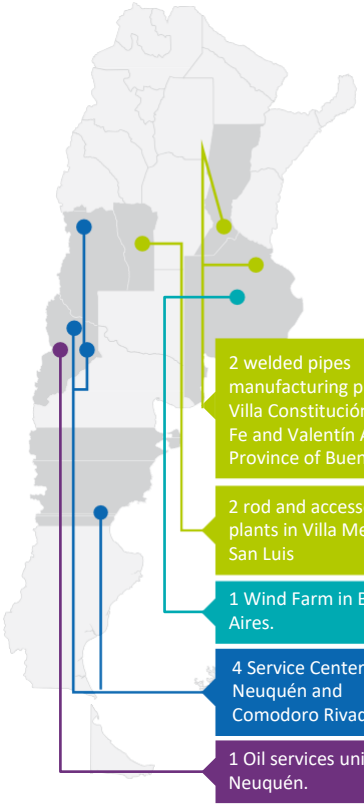
Oil and gas industry

Construction industry
Automotive industry

Mining industry

Industrial applications

Our presence in Argentina also includes:



Buena Ventura Wind Farm

Tenaris is building its first wind farm in the world in Argentina. The 24 wind turbines that will make up the Buena Ventura Wind Farm will be in Buenos Aires district Gonzales Chaves and will supply 50% of the electrical energy required by the Tenaris Industrial Center in Campana, thus generating a reduction in CO2 emissions of 152,000 tons per year.
This is a big step in our commitment to the energy transition and Tenaris's decarbonization plan towards 2030.

200 million dollars in investments

Will supply 50% of the electrical energy required by TenarisSiderca

24 wind turbines (130m high and 150m in diameter)

Innovation for the industry: Research and Development Center

We carry out specific scientific and technological research on materials, product behavior, coating development, application design and solutions for the oil industry, industrial process analysis, welding metallurgy and nanotechnology. We collaborate with external R&D laboratories, product testing centers and universities, as well as with local SMEs, through the Propymes program.

81 specialized technicians and scientists in Argentina

+60 patents generated per year

Adding value through knowledge: TenarisUniversity

The corporate university is responsible for strategically integrating, aligning and disseminating knowledge and experience throughout the company. The campus in Campana includes the Academic Building, inside the plant, and the residence where Tenaris employees from anywhere in the world who come to Argentina for training can stay.

$500,000 Annual investment in training in Argentina

+1000 own courses Face-to-face or e-learning

4,000m2 In the academic building

Close to the community: education for the new generation

We promote technical education for the future industrial world by investing in infrastructure, training students and teachers, and professional practices. In 2013, we founded the Roberto Rocca Technical School in Campana, the first of a worldwide network, with capacity for 450 students in electromechanical and electronic specialties.

1.2 billion pesos in investment in 2021

350 scholarship students annually

+500 Volunteers in Action employees and community

Technische Universität Berlin
Institute for Machine Tools and Factory Management (IWF)
Chair of Corporate Sustainable Development
Prof. Dr.-Ing. Holger Kohl

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