GCSM

18th Global Conference on Sustainable Manufacturing

"Manufacturing driving Circular Economy"

October 5 to 7, 2022

Production Technology Centre (PTZ)

Berlin, Germany

CONFERENCE BOOK

TU berlin

GPE

Fraunhofer
IPK

Sustainable
MANUFACTURING

pre
zero

» PREFACE

The Organizing Committee of the 18th Global Conference on Sustainable Manufacturing (GCSM) is happy to meet you in Berlin, Germany. This conference is jointly organized and hosted by the Production Technology Center (PTZ) Berlin of Technische Universität Berlin and Fraunhofer Institute for Production Systems and Design Technology (IPK).

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. A total of 120 contributions will be presented in parallel sessions. They are authored and co-authored by personalities from 27 countries representing all continents of the globe.

Welcome to GCSM 2022 in Berlin!

Best regards,

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

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

Prof. Dr.-Ing. Günther Seliger
(Founding Chairman)

2003	2004	2005	2006	2007	2008	2009	2010	2011
I. GCSM Alabama	II. GCSM Berlin	III. GCSM Shanghai	IV. GCSM Sao Carlos	V. GCSM Rochester	VI. GCSM Pusan	VII. GCSM Madras	VIII. GCSM Abu Dhabi	IX. GCSM St. Petersburg

2012	2013	2014	2015	2016	2017	2018	2019	2022
X. GCSM Istanbul	XI. GCSM Berlin	XII. GCSM Johor Bahru	XIII. GCSM Ho-Chi-Minh-City	XIV. GCSM Stellenbosch	XV. GCSM Haifa	XVI. GCSM Kentucky	XVII. GCSM Shanghai	XVIII.GCSM Berlin

time\date	October 5, 2022				October 6, 2022				October 7, 2022		
	Day 1: "Global Challenges for Sustainability"				**Day 2: "Circular Economy Principles and Initiatives"**				**Day 3: "Examples of Industrial Transformation"**		
8:00	Registration at Conference Site				Registration at Conference Site				Registration at Conference Site		
8:30	Conference Opening *(President TU Berlin & Conference Chairmen)*				Keynote Dr. Ballweg (SYSTEMIQ) *(Circular economy and economic decoupling)*				Keynote Mr. Kyriakis (Schwarz Gruppe) *(A new approach to the circular economy)*		
9:00	Keynote Prof. McAloone (TU of Denmark) *(Sustainable production, circularity and competitiveness)*				Keynote Prof. Jawahir (University of Kentucky) *(Sustainable manufacturing for advancing circular economy)*				Keynote Dr. Weyrauch (Dürr) *(The Dürr Group: Enabler for a sustainable transformation)*		
9:30	Keynote Prof. Sami Kara (UNSW) *(Implications of net-zero CO_{2eq} targets for environ. sustain.)*				Keynote Ms. Garcia (ISO) *(International Standards for Climate Action)*				Keynote Dr. Bohr (Industria Fox) *(Digital Ecosystems for the circular economy)*		
10:00	Keynote Prof. Dietrich (TU Berlin) *(Handling and assembly in the context of SM)*				Coffee Break				Coffee Break		
10.30	Coffee Break				**Session 9** Production Planning, Scheduling and Control	**Session 10** *Materials*	**Session 11** *Additive Manufacturing*		**Session 20** *Life Cycle and Decision Making II*	**Session 21** *Sustainability at Regional Level*	**Session 22** Advanced Digitalization
11:00	Keynote Mr. Geißler (DMG Mori) *(SM by holistic resource efficiency in machining processes)*										
11.30	Keynote Mr. Haberstock & Mr. Pult (Arnold Fasteners) *(Implementation of SDG's in mass production)*										
12:00	Keynote Dr. Kadner (acatech) *(Circular Economy Initiative Germany)*								Farewell and Outlook GCSM 2023		
12.30	Lunch				Lunch				Lunch		
14.00	**Session 1** *Supply Chain and Reman. Processes I*	**Session 2** *Energy Efficiency I*	**Session 3** *Strategy and Business Model*	**Session 4** *Industry 4.0 & Digitalization I*	**Session 12** *Energy Efficiency II*	**Session 13** Manu-facturing Processes	**Session 14** Machine Tools II	**Session 15** Production Systems I	Industry Tours/TU Berlin Research Projects		**Session I** *Student Session*
14.30											
15:00											
15.30	Coffee Break				Coffee Break						
16.00	**Session 5** *Life Cycle and Decision Making I*	**Session 6** *Metrics for Sustainable Manufac.*	**Session 7** *Machine Tools I*	**Session 8** *Supply Chain and Reman. Processes II*	**Session 16** Product Design and Innovation	**Session 17** *Industry 4.0 & Digitalization II*	**Session 18** *Learning and Knowledge*	**Session 19** *Strategy and Assessment*			
16.30											
17.00											
17.30	Buffer								End of the conference		
18.00	Welcome Reception										
18:30					Berlin City Tour by Bus						
19:30											
20:00					Conference Dinner *(until 23:00)*						
20:30											
…											

GCSM
18th Global Conference on Sustainable Manufacturing

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Dr. Shuho Yamada	Toyama Prefectural University
Dr. David Sarancic	Technical University of Denmark
Dr. Yuki Kinoshita	SECOM CO., LTD

» KEYNOTE LECTURES

Keynote 1:

Wed, October 5th, 9:00 – 9:30 a.m., Room PTZ S001

Title: Sustainable production, circularity and competitiveness: Finding our way through the opportunities

Professor Tim McAloone

Technical University of Denmark, *Department of Civil and Mechanical Engineering*

Abstract

The sustainability agenda has manifested itself significantly over recent years, not least within production companies, which are setting strategic goals and targets, like never before. Ecodesign, Sustainable Production, Science Based Targets, Circular Economy – the initiatives are many and the ambitions high. But when many new ideas, demands and ambitions land all at the same time in a company, clear dilemmas and difficult choices arise, when good intentions should become prioritised goals – and when prioritised goals should be translated into actions. This keynote will highlight some of the most important challenges observed in modern production companies today and will provide reflections on how challenges can be turned into benefits.

Keynote 2:

Wed, October 5th, 9:30 – 10:00 a.m., Room PTZ S001

Title: Implications of net-zero CO_{2eq} targets for environmental sustainability

Professor Sami Kara

UNSW, School of Mechanical and Manufacturing Engineering

Abstract:

The global society faces an existential threat if it fails to meet current and future material needs of its citizens, while staying within the carrying capacity of our planet. In their 2018 report, the Intergovernmental Panel on Climate Change (IPCC) stated that limiting the Green House Gas (GHG) emission and associated global warming below or close to 1.50C would require deep emission reduction to reach net zero by 2050. The dire warning of the recent IPCC report in 2022 has further stated the urgency of the matter and call for immediate action. Greenhouse gas accountings, commonly referred to with the popular term carbon footprints (CFP), are a widely used metric of climate change impacts and the main focus of many as in the IPCC report. However, environmental sustainability concerns not just climate change but also eight other environmental impact dimensions, such as land system change, ocean acidification, fresh water use etc. Furthermore, these environmental impact dimensions are mutually dependent; hence the focus on CFP brings the risk of problem shifting at the expense of increase in other environmental impacts, which may eventually lead to increase in GHG emission.

This keynote talk will discuss when carbon footprint is a good and poor representative of the environmental burden of products, and environmental management focused exclusively on CFP runs the risk of inadvertently shifting the problem to other environmental impacts. Unless CFP has been demonstrated to function well as overall environmental impact indicator for the product or technology under investigation, it should be used as a 'temporary indicator', towards environmental sustainability.

Keynote 3:

Wed, October 5ᵗʰ, 10:00 – 10:30 a.m., Room PTZ S001

Title: Assembly and Disassembly in the context of circular economy

Professor Franz Dietrich

TU Berlin, Chair of Assembly and Handling Technology

Abstract:

A circular economy of materials, which are manufactured into goods, used as products, maintained to maximize usage lifespan, and re-circulated for further usages, has immanent need for assembly, disassembly, and handling. However, it is not to be mistaken that circularity can be achieved at all and that this is leading to absolute sustainability; mainly, this is because of unrenewable energy supply, ineffective processes, insufficiently large material flows, and/or unfavorable market situations. In this sense, purposeful innovations in assembly, disassembly, and handling consider these restrictions, for example by maximizing process efficiency through the optimum level of digitalization or automation. This keynote speech links current concepts of circularity and sustainability with such technological innovations in assembly, disassembly, and handling. Examples from own research and beyond are used to illustrate the different points in the value creation streams. Future research directions in energy storage production and cloud production are laid out.

Keynote 4:

Wed, October 5th, 11:00 – 11:30 a.m., Room PTZ S001

Title: Sustainable Manufacturing by Holistic Resource Efficiency in the Machining Process and in the Machine Tool

Alfred Geißler

Member of the Executive Board at DECKEL MAHO Pfronten GmbH and DECKEL MAHO Seebach GmbH

Abstract:

DMG MORI AKTIENGESELLSCHAFT is a worldwide leading manufacturer of machine tools and is actively advancing the future fields of automation, digitalization, and sustainability. At DMG MORI, sustainability and technology leadership have been in harmony for many years.

Customers' purchasing decisions are increasingly based also on sustainability aspects, like the footprint of the machine and the machine's energy consumption in operation. Consequently, sustainable manufacturing requires to focus on both the machine tool as a product and the machining process as a service.

DMG MORI focuses with its DMG MORI GREEN ECONOMY on the entire value chain. Within this, the GREEN MACHINE initiative already achieves the 100 % climate-neutrally produced machine by applying the climate triad „Avoid – Reduce – Compensate". Besides the product focus, DMG MORI also includes a process focus by the initiatives GREEN MODE and GREEN TECH. GREEN MODE aims for the resource-efficient machine operation at the customer's site. DMG MORI machines are highly productive and operate with up to 30% reduced energy consumption in standard. With GREEN TECH, customers are empowered to pioneer in innovating and producing green technologies.

Keynote 5:

Wed, October 5th, 11:30 – 12:00 a.m., Room PTZ S001

Title: Fastening Sustainability. Implementation of SDG´s in mass production in countries with different cultures and different technology levels

Reiner Haberstock

CEO of Arnold Fasteners Shenyang

Michael Pult

Director Marketing of Arnold Umformtechnik

Abstract:

Arnold Umformtechnik GmbH und Co. KG is a German SME, founded in 1898, producing fasteners and special cold-forming parts mainly for the global automotive supply chain. At present around 1000 employees working in Germany at 3 different locations. The sister company Arnold Fasteners Shenyang, was founded in 2007 in North East China to supply the global automotive customers with local made parts, following the strategy "we are where our customers are" and "local to local" to penetrate the Chinese automotive supply chain. Around 250 employees are

Both companies are part of the Wuerth Group, one of the biggest Trading companies globally for Fasteners and Assembly material, available in 85 Countries, with more then 400 Companies, nearly 80.000 employees and a global turnover of more then 14 Bio. Euro in 2021.

With this presentation the authors want to explain, based on real projects, how small and medium sized enterprises are working on the topic of Sustainability. This especially with the impact of operating on different technology levels, different development stages of the company life-cycle (125 years vs. 15 years), different legal frameworks / regulations and very different cultural environments.

Keynote 6:

Wed, October 5th, 12:00 – 12:30 a.m., Room PTZ S001

Title: Circular business models and digital technologies – leveraging the potentials of a Circular Economy

Dr. Susanne Kadner

Director Circular Economy Initiative Germany and Lead of Energy, Resources and Sustainability at National Academy of Science and Engineering (acatech)

Abstract:

Current research shows that our prevailing mode of resource production and consumption leads us to crossing multiple planetary boundaries. The transition towards a Circular Economy carries the potential to addressing the numerous dimensions of our current environmental problems while dealing with increasing supply chain risks at the same time. Extending the life cycle of products and components, intensifying product use and drastically increasing recycling can contribute to comprehensive greenhouse gas emissions and resouce savings. Circular business models will play a decisive role in facilitating the implementation of these circular strategies but they require a fundamental rethink of doing business – both for customers and companies alike. For the majority of these busniess models, digital technologies constitute a key enabler. Examples from current research projects illustrate the potential and possible applications.

Keynote 7:

Thu, October 6th, 8:30 – 9:00 a.m., Room PTZ S001

Title: Circular Economy and economic decoupling: Why recycling alone cannot solve the resource challenge and what policy can do to help

Dr. Matthias Ballweg

Lead EU policy and mobility at SYSTEMIQ, joint responsibility with the World Economic Forum for Circular Car Initiative and architect of further coalitions like the Battery Passport Consortium

Abstract:

The European industry facing the biggest and deepest change in its history. Climate change, urbanization and societal upheaval are leading to changing customer demands and there is an imperative that asks us to reduce not only our CO2-footprint drastically, but also our material footprint. Currently all trends still point into the opposite direction: e.g., cars are getting heavier and more every year. Matthias Ballweg shows how these effects counter existing circular economy efforts like remanufacturing and recycling and shows the scale of the industry change that is needed to actually fulfil an IPCC target of 1.5°Celsius. With specific examples from the mobility industry he illustrates the vulnerability of global supply chains and explains how a systemic implementation of the EU green deal can help to make business models of European companies not only more circular and aligned with climate targets, but also more resilient against economic shocks.

Keynote 8:

Thu, October 6th, 9:00 – 9:30 a.m., Room PTZ S001

Title: Sustainable Manufacturing for Advancing Circular Economy: Technological Challenges and Opportunities for Producing Sustainable Products from Sustainable Manufacturing Processes

Prof. Ibrahim S. Jawahir

University of Kentucky, Institute for Sustainable Manufacturing (ISM)

Abstract:

Recent trends in sustainable manufacturing (SM) literature clearly indicate the significant efforts made by the global research community to develop and implement SM technologies for achieving economic, environmental, and societal benefits. Moreover, the technological elements of circular economy (CE) are also often associated with multiple closed-loop material and information flows established in defining and promoting SM. However, in current practice, the interactions and interdependence between SM and CE are often ignored or minimally utilized in product/process development for SM. This is largely due to the perceived, and only partially correct, interpretations of CE, that takes siloed approaches to develop technological needs/requirements for implementing CE. This effect is compounded by the lack of knowledge about the integral technological elements of CE derived from SM.

This paper will focus on presenting opportunities for sustainable value creation in all involved technological elements of CE through product and process innovations. This includes design of 6R-based total life cycle considered products and associated manufacturing processes to facilitate SM. Furthermore, identification of pertinent sustainability metrics and their applications for products and processes will be emphasized with a view to producing sustainable products from sustainable manufacturing processes. The need of concurrent product and process design for sustainability for creating such sustainable values will also be discussed. Sustainable value creation in closed-loop SM will be shown as the basis for achieving and advancing CE. Therefore, enablers and contributors to sustainable value creation in products and processes will be presented and discussed with value chain analysis for sustainable manufacturing of sustainable products. Notably, the principles and practices of SM will be shown as the foundational requirements for achieving and advancing the CE across the board. Finally, the significance of considering closed-loop SM for advancing CE as a major driver for progress in all 17 UN's Global Sustainable Development Goals (SDGs) to achieve universal environmental, economic, and societal benefits will be highlighted.

Keynote 9:

Thu, October 6ᵗʰ, 9:30 – 10:00 a.m., Room PTZ S001

Title: International Standards for Climate Action

Ms. Noelia Garcia Nebra

Head of Sustainability, ISO – International Organization for Standards

Abstract:

The world needs urgent and collective climate action from governments, standard setters, businesses, and all aspects of society to limit global warming to well below 2 °C degrees. International Standards have a vital role in supporting government, industry and civil society in adapting to and mitigating the impacts of climate change as well as accelerating the transition to zero-carbon economies. ISO, the International Organization for Standardization is the world's largest standards developer. It provides a platform for national experts from all sectors to meet and develop global consensus-based standards.

ISO and its member national standards bodies have committed to align International Standards with climate action. This means we are putting climate action at the heart of all standards development and will be actively working with partners to ensure existing and new standards are climate-aligned to ensure that climate commitments are transformed into effective actions.

Keynote 10:

Fri, October 7th, 8:30 – 9:00 a.m., Room PTZ S001

Title: A new approach to the circular economy

Thomas Kyriakis

CEO PreZero Stiftung & Co. KG

Abstract:

How do we succeed in closing loops and preserving resources? How can we create something new from what already exists? And how can we achieve a turnaround towards a sustainable future in which an efficient recycling loop protects our environment? An answer to all these questions is provided by Thomas Kyriakis, CEO of PreZero. The internationally operating environmental service provider PreZero is moving forward with new thinking for a cleaner tomorrow.

Because here the name says it all: PreZero wants to reduce the amount of waste that cannot be recycled towards zero. As part of the Schwarz Group, PreZero is active in the entire recycling loop - from production and retail to waste and recycling management, which is unique worldwide within a corporate group.

Keynote 11:

Fri, October 7th, 9:00 – 9:30 a.m., Room PTZ S001

Title: The Dürr Group: Enabler for a Sustainable Transformation.

Dr. Jochen Weyrauch

CEO Dürr AG

Abstract:

Mechanical and plant engineering is one of the most important sectors in the energy transition and fight against climate change. Its Innovative technologies enable both: the increased use of renewable energies and maximum energy efficiency in industrial manufacturing processes. Therefore, mechanical and plant engineering plays a key role in reducing global greenhouse gas emissions through its interconnection in all relevant industrial sectors. The Dürr Group stands for modern, climate-oriented production equipment and considers sustainability as an opportunity: Dürr technologies help customers to lower their energy consumption in production, reduce their ecological footprint and to manufacture sustainable products. With its climate strategy adopted in 2021, the Dürr Group has defined ambitious target for the reduction of its own carbon footprint and helps to meet the 1.5-degree from the Paris Climate Agreement.

Keynote 12:

Fri, October 7th, 9:30 – 10:00 a.m., Room PTZ S001

Title: Digital Ecosystems for the Circular Economy

Dr. Philipp Bohr

President of the Board at Indústria Fox Economia Circular; Founder and CEO of Yes Ecosystems Technology; President at IECE

Abstract:

With shattered and dysfunctional globalized value chains in the context of geopolitical divide and climate change, ensuring access to raw materials and securing their timely supply regains center stage in the development of economically sustainable manufacturing strategies. As a result of related challenges, decision-makers across the globe might be tempted to deprioritize their focus on advancing the green economy agenda, which intends to establish environmentally sustainable circular value chains in conjunction with the concept of extended producer responsibility.

However, digital management ecosystems and robotic process automation (RPA) that orchestrate multi-stakeholder process flows in a cloud-based digital and collaborative work environment hold the potential to fundamentally alter the economics of local circular value chains and urban mining. Instead of having to be considered an additional burden, managers that adopt circular economy thinking and leverage these technologies can empower their organizations to regain strategic control over raw material supply chains while outperforming competitors on the environmental agenda.

The use of digital ecosystems and RPA to automate, control and steer circular value chains that include relationship management with thousands of consumers in the role of initial raw material suppliers is being illustrated with a case study from Brazil. Exploring the example of a take-back scheme for waste from electrical and electronic equipment in connection with carbon credits as incentives for consumer participation, the disruptive potential of these technologies is shown in the context of sourcing polystyrene plastics in association with environmentally-driven individual producer responsibility systems for a global white goods manufacturer.

Wed, 5th October - 14:00 - 15:30			
Paper Session 1 Sustainable Manufacturing Processes - **Supply Chain and Remanufacturing Processes I**	**Paper Session 2** Sustainable Manufacturing Systems - **Energy Efficiency I**	**Paper Session 3** Crosscutting Topics in sustainable Manufacturing - **Strategy and Business Model**	**Paper Session 4** Sustainable Manufacturing Systems - **Industry 4.0 & Digitalization** I
Room PTZ S001	Room PTZ S112	Room PTZ 001	Virtual Session
reProd® - resource-autarkic production based on secondary semi-finished products (ID 97)	Development of a holistic framework for identifying energy efficiency potentials of production machines (ID 34)	Identification of Action Areas For The Promotion of Local Manufacturing In Reference To System Theory (ID 89)	Conceptual framework of a digital twin fostering sustainable manufacturing in a brownfield approach of small volume production for SMEs (ID 78)
Reducing remanufacturing uncertainties with the digital product passport (ID 145)	Simulation-based efficiency comparison of different mains configurations for DC grid branches for supplying production plants based on a rule-compliant design (ID 16)	Role of recycling towards a sustainable business model: A perspective on industrial assets (ID 140)	Pharma 4.0: Revealing drivers of the digital transformation in the pharma sector (ID 28)
Digital Supply Chain Twins for Sustainable Planning of a Logistics System (ID 42)	Increasing Energy Efficiency and Flexibility by Forecasting Production Energy Demand Based on Machine Learning (ID 11)	Consumer perceptions of the circular business model: a case of leasing strollers (ID 162)	A Case Study on Evaluation of Defect Characteristics for Practical Application of Appearance Inspection Work Support System Utilizing Deep Learning (ID 39)
Optimization of a remanufacturing production planning system with the help of artificial intelligence (ID 65)	The Use of Gentani Approach for Benchmarking Resource Efficiency in Manufacturing Industries (ID 41)	Guideline for Identifying Required Data Granularity for Deriving Improvements to the Environmental Impact of Production (ID 81)	Framework for the development and implementation of sustainable information systems for the digitalization of small businesses in South Africa (ID 50)
Circular Supply Chain Management in the Wind Energy Industry – A Systematic Literature Review (ID 134)	Increase efficiency of energy transmission by incentives (ID 51)	Sustainability impacts of global used clothing trade and its supply chain (ID 70)	Sustainable Solutions by the Use of Immersive Technologies for Repurposing Buildings (ID 29)

Paper Session 1: Sustainable Manufacturing Processes - Supply Chain and Remanufacturing Processes I
Wed, 5th Oct - 14:00 - 15:30, Room PTZ S001

rePROD® - resource-autarkic production based on secondary semi-finished products (ID 97)

Markus Werner, Rico Haase, Christian Hermeling

Fraunhofer Institute for Machine Tools and Forming Technology, Reichenhainer Str. 88, 09126 Chemnitz, Germany

Abstract: This paper presents a novel approach of a smart shortened material loop for producing second-life metallic components by saving a significant amount of energy and CO_2 emissions. The focus is on metallic components and manufacturing chains based on adapted forming technologies. Sourcing and using secondary semi-finished products instead of virgin metallic materials facilitates the omission of process steps, such as iron smelting, steel making, continuous casting, hot and cold rolling, which involve the highest energy consumption and the highest CO_2 emissions. Besides the positive impacts on sustainability, there are still scientific and technological challenges. One challenge lies in matching providers of secondary semi-finished material to market needs; the other comprises engineering the forming process chain while some material characteristics are not clearly specified or vary in a wide range. In contrast to the heavily restricted properties of virgin material, the characteristics of secondary semi-finished materials vary in a wider range and need to be elaborated. In the end, a new component will be produced, differing in design, function, and properties from conventional, single-life cycle products. Therefore, this paper introduces a novel, circular material loop for metals. The paper finishes with a short concept note on digital material and product passports to store and provide the required information on properties.

Keywords: material loop, metal recycling, secondary semi-finished products

Reducing remanufacturing uncertainties with the digital product passport (ID 145)

Viola Gallina[1], Barna Gal[1], Adam Szaller[2], Daniel Bachlechner[1], Elisabeth Ilie-Zudor[3], Wilfried Sihn[1,4]

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Abstract: In contrast to the linear production model, the circular economy aims to close the loop of materials. One part of this approach is remanufacturing, which extends the lifetime of products. Various stakeholders in the supply chain are involved in remanufacturing. This makes the management and optimization of remanufacturing activities complex. The data required for optimization is often missing, which leads to uncertainties. A new European Commission initiative, the digital product passport (DPP), is believed to facilitate information exchange in the supply chain and cloud be a good solution to reduce uncertainties. The primary purpose of this paper is the quantification and evaluation of the advantages of the DPP. Based on real industrial data, a discrete event simulation model of a remanufacturing system with three production lines was developed. The authors suppose the hypothetical existence of a DPP and illustrate the benefits arising from its application.

Keywords: digital product passport, simulation, evaluation, uncertainties

Digital Supply Chain Twins for Sustainable Planning of a Logistics System (ID 42)

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Abstract: Digital Supply Chain Twins (DSCT) are gaining more and more attention both in science and in practices. They are considered to be one of the most disruptive technologies in logistics and supply chain management. In the literature, there are a variety of DSCT benefits in the case of planning and control a logistics system. Some of these potentials could also be highly suitable for the use case of sustainable and resource-efficient logistics, which, however, have been insufficiently explored in research so far. This paper will investigate to what extent the DSCT can be used to enable sustainable network planning and which potentials the DSCT implies for the predictive planning within logistics systems. Building on a literature review and interviews with industry experts a case study was conducted at a business partner in the automotive industry.

Keywords: Digital supply chain twin, logistics, supply chain, sustainability, planning

Optimization of a remanufacturing production planning system with the help of artificial intelligence (ID 65)

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Abstract: Although production planning in remanufacturing systems has attracted great interest from the research community, only a couple of real industrial applications can be perceived. Additionally, in real cases, companies are faced with manufacturing multiple products, which further complicates remanufacturing production planning (RPP). Therefore, there is a need to optimise RPP where manufacturers are involved in remanufacturing multiple products. Also optimized systems should consist of a number of uncertainties, such as the uncertain quality of the returned products. Because of these uncertainties the manufacturers have to use new parts or components – with both higher environmental impacts, as well as costs. In the present paper a line balancing scheduler of a remanufacturing system is presented – focusing on the disassembly, machining and reassembly of parts. The objective of the paper is the reduction of usage of the energy and cost intensive new parts with production scheduling using a genetic algorithm (GA). The achievements are illustrated and presented with a real industrial use case from a gas engine producer. A discrete event simulation (DES) is used for evaluation purposes and the results from the scheduler are compared with benchmarks of the current production planning of the gas engine manufacturer.

Keywords: remanufacturing, genetic algorithm, production planning, simulation, uncertainties

Circular Supply Chain Management in the Wind Energy Industry – A Systematic Literature Review (ID 134)

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Abstract: The shift to a circular economy and the use of wind energy are key components in achieving the climate goals that some governments like Germany have set for themselves. Nevertheless, the wind energy industry is still predominantly organized as a linear system. Therefore, this paper outlines the existing research on the wind energy supply chain and embeds it in the context of a circular economy. The results show that some aspects of the circular economy have recently gained attention. For instance, the recycling of wind turbine blades is often discussed in literature. However, circular thinking is still underrepresented in supply chain management research. For example, studies on return, recover and deliver processes are rare. By presenting a structured overview of the current state of research, an agenda for future investigations can be derived. Hence, this publication makes a clear contribution towards becoming more circular in the wind energy supply chain.

Keywords: Circular Supply Chain Management, Sustainability, Circular Economy, Wind Energy, Literature Review, Supply Chain Management

Paper Session 2: Sustainable Manufacturing Systems - Energy Efficiency I
Wed, 5th Oct - 14:00 - 15:30, Room PTZ S112

Development of a holistic framework for identifying energy efficiency potentials of production machines (ID 34)

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Abstract: A prerequisite to identify energy efficiency potentials and to improve energy efficiency is the measurement and analysis of the energy demand. However, in industrial practice, approaches to identify energy efficiency measures of production machines are associated with high costs for metering equipment and time consuming analysis requiring expertise. Against this background, this paper describes a comprehensive and cost-efficient framework from acquisition to analysis of energy data to serve as a starting point to increase energy efficiency in manufacturing. For this purpose, an energy transparency and analysis system is being developed that can measure, record and analyze electrical quantities. The validity of the data acquisition can be verified by utilizing a Raspberry Pi as a low-cost edge analyzer device. Measurement data is stored with associated metadata in a SQLite database for subsequent processing in a Python-based web application, in which machine learning algorithms can be deployed. The algorithms can be used to process vast amounts of data and to provide a basis for calculating energy performance indicators to reveal energy efficiency potentials. The overall workflow is validated using a lathe and a cleaning machine within the ETA Research Factory at the Technical University of Darmstadt.

Keywords: energy transparency, data acquisition, sustainable manufacturing

Simulation-based efficiency comparison of different mains configurations for DC grid branches for supplying production plants based on a rule-compliant design (ID 16)

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Abstract: Numerous research projects are investigating direct current (DC) grids for supplying energy to production plants. The motivation is the higher efficiency and lower material requirements compared to conventional grid structures, as fewer electrical conversion processes occur, regenerative energies can be coupled in more efficiently and recuperation energy can be stored better. The grid form and the associated earthing concept require different protective devices. The publication simulates two possible grid forms and compares the efficiency with an approximated power curve of a production cell. The publication gives researchers and plant planners an impression of how such a network is designed and which components influence the efficiency. It serves as a decision-making aid for the selection of the grid form and helps with the design of the electrical components.

Keywords: Power grid, DC-Microgrid, simulation, energy efficiency, grounding method

Increasing Energy Efficiency and Flexibility by Forecasting Production Energy Demand Based on Machine Learning (ID 11)

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Abstract: The ability of manufacturing companies to compete depends strongly on the efficient use of production resources and the flexibility to adapt to changing production conditions. Essential requirements for the energetic infrastructure (EGI) result from the production itself, e.g., security of supply, efficiency and peak shaving. Since production always takes priority and must not be disturbed, the flexibility potential in terms of energy efficiency lies primarily in the EGI. Based on this, strategies will be developed that support companies in increasing their efficiency and flexibility by optimizing the configuration and operation of the EGI, while production processes are reliably supplied and not adapted. This is reached with intelligent operation strategies for the heating and cooling network based on forecasts, the use of energy storage systems, and the coupling of energy sectors. This paper presents an approach for energy forecasts used for the optimization of operation strategies. Hence, an energy-forecast-tool was developed, which is used for the prediction of electrical and thermal loads depending on the expected production. Therefore, machine learning models are trained with past weather, energy, and production data. Using production planning data and weather forecasts, the model can predict energy demands as input for an EGI optimization.

Keywords: energy efficiency, forecasting, machine learning

The Use of Gentani Approach for Benchmarking Resource Efficiency in Manufacturing Industries (ID 41)

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Abstract: The majority of today's manufacturing processes are based on well-developed and well-established procedures that are characteristic of mature technologies. The manufacturing industries have not evolved significantly over time because of recent economic, environmental, and societal advances at an unprecedented rate. As a result, there are numerous challenges and opportunities available, especially regarding resource efficiency. The majority of industrial processes consume far more energy than the theoretical minimal process energy requirements. This paper aims to develop a theoretical framework utilising the Gentani approach whilst targeting the minimum resources needed to carry out a process for use by manufacturing industries. The resource efficiency (exergy) metric has also been discussed that can be used as a tool to evaluate the efficiency of industry, depicting a more holistic level of energy and material consumption. The framework will help manufacturing industries in lowering costs and remain competitive by improving resource efficiency, aimed at reducing resource use and providing value delivery. The study will also assist in transforming these industries into resource-efficient modern manufactories in line with the Net-Zero 2050 agenda.

Keywords: Manufacturing, Net Zero, Gentani, Resource Efficiency, Exergy

Increase efficiency of energy transmission by incentives (ID 51)

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Abstract: The sustainability of manufacturing processes can be monitored by various key performance indicators and usually has a positive impact on the operating result. There are thus direct incentives to maximize efficiency and sustainability. The situation is different for the transmission of electrical energy. Energy transmission and distribution are generally regulated economic sectors in which incentive regulation methods are used to ensure economic efficiency. The current regulations provide only limited incentives for the energetic and ecological efficiency and sustainability of the transmission and distribution of electrical energy. With this paper a key figure is presented that enables a better consideration of ecological aspects in the incentive regulation. This creates a better incentive to increase transmission efficiency, which has a direct positive impact on all downstream manufacturing processes.

Keywords: electrical energy, energy transmission, incentives, regulations, sustainability

Paper Session 3: Crosscutting Topics in sustainable Manufacturing - Strategy and Business Model
Wed, 5th Oct - 14:00 - 15:30, Room PTZ 001

Identification of Action Areas For The Promotion of Local Manufacturing In Reference To System Theory (ID 89)

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Abstract: Industrial value creation today is characterised in many sectors by globally distributed processes for product manufacturing based on the division of labour in order to achieve advantages through specialisation, scale and location. However, the economic advantages of this form of value creation are being increasingly diminished by the current ecological and social challenges. Local manufacturing has the potential to be a piece of the puzzle in the complex transformation process towards a sustainable circular economy. However, suitable framework conditions are needed for the successful implementation of economically, ecologically and socially sustainable forms of local value creation. To be able to develop these in a targeted manner, knowledge regarding the areas influenceable by societal functional systems (e.g. politics, economy, production) and how they may affect the design dimensions of local manufacturing is necessary. A systems theory-based analysis is used to consider the influence of the operations of societal subsystems on local manufacturing, to identify decision spaces and to evaluate overarching couplings between the societal system operations.

Keywords: Local manufacturing, Collaborative Value creation, Sustainable Manufacturing, Circular Economy, System theory

Role of recycling towards a sustainable business model: A perspective on industrial assets (ID 140)

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Abstract: Equipment manufacturers (EMs) exhibit unsustainable operating patterns in linear production models by depleting finite materials. In this context, business environments in industrial markets shift fundamentally and form a new sustainability paradigm stimulated by key drivers, e.g., customer behavior, and regulation. Future economic viability increasingly inherits ecological considerations requested by the EMs' stakeholders. This transforming environment requires a re-evaluation of sustainability approaches, together with profitability objectives. Prior research exhibited common R-principles, e.g., "reuse", "remanufacture", and "recycle", fostering either an extension of the product life cycle or yielding a reintroduction of raw material into the cycle. Recycling is instrumentalized for some materials, e.g., polyethylene terephthalate. For industrial assets, i.e., manufactured products, recycling efforts fall short. Investigating this shortage and market shift, the study (1) scrutinizes the role of recycling and provides an overview of prerequisites in the transition towards a sustainable business model, (2) identifies characteristics of industrial assets facilitating recycling, and (3) evaluates parameters to operationalize a recycling value chain (RVC). The analysis of quantitative data of a globally operating Swiss EM and qualitative data proposes key drivers and characteristics facilitating the recycling of industrial assets and parameters fostering RVCs. Future research should increase the number of EMs to exceed limitations.

Keywords: Industrial asset, parameter, recycling value chain, sustainable business model

Consumer perceptions of the circular business model: a case of leasing strollers (ID 162)

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Abstract: Circular Economy (CE) promotes trading functions of a product as a service instead of selling the product in conventional ways. For a product like a baby stroller, the function means ensuring mobility with infants without needing to own a stroller. This approach of acquiring functions only when needed opens up the possibility to share the same products with multiple users. For a manufacturer that has built its business on a conventional sales model over the decades, this shift may be too radical. Therefore, for the manufacturers, it is important to understand consumer perceptions of the service-oriented business model before entering this unknown territory. To develop a thorough understanding of consumer perceptions of leasing a stroller instead of buying one, a survey among 200 parents in Stockholm is conducted. The survey brings out quantitative results such as 39% of respondents are open to leasing and identifies key influencing factors such as convenience and environmental image that play a key role for the remaining 61% of respondents to choose leasing. This research concludes that a large number of consumers are open to leasing if a high level of service and environmentally sustainable strollers are offered at a competitive price.

Keywords: Circular Economy, business model, leasing, service-oriented, consumer perceptions

Guideline for Identifying Required Data Granularity for Deriving Improvements to the Environmental Impact of Production (ID 81)

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Abstract: Various sustainability reporting tools (SRTs) already exist, such as ISO 14001, Carbon Disclosure Project (CDP), and Greenhouse Gas Protocol (GGP). However, these tools focus on calculating total environmental impact for reporting to external parties, rather than providing guidance to a company on obtaining measures needed to identify improvement potentials within its production. This is due to low granularity of data measurements dictated by the SRTs, since insights only available from higher granular data are typically needed to derive actionable improvements. Understandably, differentiating for which processes higher granularity is needed is not always straightforward. Thus, this paper presents a guideline concept to support manufacturers in determining the required data and data granularity to identify improvement potential, while also assessing the ecological impact of their production. Firstly, energy consumption (electricity and heat), water and material use are determined to be the most relevant measures. Secondly, a structured categorization of production steps is created. As a starting point, selected metal working processes according to DIN 8580 are incorporated into the guideline. Thirdly, the data/device hierarchy from the Reference Architecture Model Industry 4.0 (RAMI 4.0) is used to define three data granularity levels. Finally, a structured approach for determining ideal data granularity for each production step is developed and applied to build an initial version of the guideline. An evaluation shows that the guideline recommends appropriate data granularities, promising to be a useful tool for manufacturers wanting to improve their ecological impact.

Keywords: Data Granularity, Environmental Impact, Production

Sustainability impacts of global used clothing trade and its supply chain (ID 70)

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Abstract: Global trade of used clothing, which comprises a series of activities that connect Global North to Global South, has grown substantially over the years. This paper analyses the trade data of export/import trade of used clothing to provide an overview of global trade statistics and explores the sustainability impact of the used clothing trade. Both qualitative and quantitative secondary data were employed in the study. Analysis of export data revealed a declining trend, which may be attributed to the import bans of used clothing and new cheap imports from Asia. While the United States is constantly being the top exporter, and Pakistan is the top importer, the value of exports grew the fastest in China during the last decade. Analysis of sustainability impacts revealed both positive and negative facts. Used clothing markets support thousands of livelihoods and provide affordable clothing for those who live in poverty; however, the fast fashion phenomenon is threatening this important trade. Therefore, this study urges to investigate alternative business models to reutilize clothing waste. Remanufacturing and recycling-based business models, when implemented in the Global South, could provide viable solutions to reutilize excess clothing while enhancing the sustainability benefits. Building up collaborative relationships among the stakeholders of the used clothing supply chain is immensely necessary to develop such disruptive business models and to capture values along the supply chain.

Keywords: Used Clothing, Sustainability, Supply chain

Paper Session 4: Sustainable Manufacturing Systems - Industry 4.0 & Digitalization I
Wed, 5th Oct - 14:00 - 15:30, Virtual Session

Conceptual framework of a digital twin fostering sustainable manufacturing in a brownfield approach of small volume production for SMEs (ID 78)

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Abstract: SMEs are increasingly forced to shift to more sustainable manufacturing. Industry 4.0 can support the transformation and foster innovation. But, SMEs need solutions with a low barrier to entry in terms of investment, IT knowledge and capacities. A framework based on value and material flow analysis, low investments and user-oriented IT skills is proposed. As an example, it is implemented in the furniture industry and shows a digital twin in terms of monitoring the energy and material flows. In addition, a product-specific allocation of energy consumption, energy peak shaving and other applications are possible.

Keywords: Industry 4.0 technology, green transformation of manufacturing

Pharma 4.0: Revealing drivers of the digital transformation in the pharma sector (ID 28)

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Abstract: The primary goal of this paper was to uncover the drivers of digital transformation (DT) in the pharmaceutical industry. The Covid-19 pandemic and tightening regulatory standards in the global pharma industry necessitated pharma executives' need to understand the most critical drivers of digitalizing the sector and charting a new path that improves production processes and streamlines these companies' overall supply chain. This research aims to identify the drivers for DT in the pharmaceutical industry. The Web of Science Core Collection and Scopus gathered relevant data for the research study. The research employs objective analysis to ensure that more reliable conclusions were drawn following the study. The study also proposed that external and internal factors, such as supply chain difficulties and data silos, impact DT adoption in the pharmaceutical sector.

Keywords: Digital transformation, Industry 4.0, Pharma 4.0, Pharmaceutical industry, Supply chain complexities.

A Case Study on Evaluation of Defect Characteristics for Practical Application of Appearance Inspection Work Support System Utilizing Deep Learning (ID 39)

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Abstract: To prevent outflow of defective products to customers, many manufacturing industries have focused not only on processing and assembling, but also on product inspection. In appearance inspection, a work support system using deep learning has been proposed, and its usefulness was experimentally shown in model images of industrial product in recent years. Therefore, in this study, aiming for practical application of work support system, the relationship between the lighting angles and the visibility of defects is experimentally evaluated using 80 actual automobile parts as a case study. As results, it is found that the visibility of the defect greatly differs depending on the angle of lighting, and the conditions for high visibility differ depending on the defect. Furthermore, it is found that it is possible to improve the visibility of defects in about 24% of all 80 automobile parts, but, it is difficult to improve the visibility of defects for the remaining 76%. From the above, for the practical application of the work support system, it is clarified that the importance of constructing of lighting condition optimization method to improve the visibility of defects, and examining the input image considering the visibility of defects for deep learning.

Keywords: Appearance Inspection, Work Support, Machine Learning

Framework for the development and implementation of sustainable information systems for the digitalization of small businesses in South Africa (ID 50)

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Abstract: In this paper, a framework for the development and implementation of a low-cost, "low-code", information system, for the digitalization of small businesses, in the retail and manufacturing sectors is developed and employed. The purpose of this framework is to enable small businesses, that lack the technical expertise and financial resources to invest in proprietary information system technology, to develop systems by leveraging freely available cloud-based tools like Google Forms, Google Sheets, and Google Sites. A thorough literature review of the concept of digitalization is conducted. Thereafter, a small business suitable for digital transformation is identified. Based on the system requirements an information system relevant to the business is developed and implemented. Finally, guidelines are proposed for the development and implementation of similar systems in other small businesses.

Keywords: framework, digitalization, information system

Sustainable Solutions by the Use of Immersive Technologies for Repurposing Buildings (ID 29)

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Abstract: In the context of urban production and sustainable reuse of existing buildings, a detailed planning of the later usage is indispensable. One approach is to enable large-scale AR simulation on site with a sufficient Level of Detail (LoD) and stability. To determine performance metrics, a technology-stack is created and presented that enables a realistic field experiment in an industrial environment (area of 1,314 m²) using Microsoft HoloLens 2. For the experiment, a 3D model was instantiated as often as possible up to the limit of system stability and in different LoDs (100% down to 10%). The result shows that it is feasible to represent 2.63 million polygons (equivalent to about 1,909 m3 of augmented space) on LOD-35%; LoD-100% is equivalent to 327.38 m3 and 1,284 million polygons. Polygonal density [polygons/m³] is introduced as new indicator for better comparability when using 3D models. Thus, it is possible to immersively visualize urban production planning processes in large-scale scenarios. This expands the functional planning space of Urban Production and overcomes previous technical limitations.

Keywords: Augmented Reality, Urban Production, Large Scale Industry Scenario, Industrial Metaverse, Stability, Resilience, Rendering, Performance, Sustainability

Wed, 5th October - 16:00 - 17:30			
Paper Session 5 Sustainable Manufacturing Systems - **Life Cycle and Decision Making I**	**Paper Session 6** Crosscutting Topics in sustainable Manufacturing - **Metrics for Sustainable Manufacturing**	**Paper Session 7** Sustainable Manufacturing Processes - **Machine Tools I**	**Paper Session 8** Sustainable Manufacturing Processes - **Supply Chain and Remanufacturing Processes II**
Room PTZ S001	Room PTZ S112	Room PTZ 001	Virtual Session
Framework for Sustainability in Aerospace: A Proof of Concept on Decision Making and Scenario Comparison (ID 188)	Taxonomy for Biological Transformation principles in the manufacturing industry (ID 133)	Influence of additivation of bio-based lubricants on sprayability and solubility for cryogenic minimum quantity lubrication (ID 110)	Analysis of Elementary Technology Considering the Remanufacturing of Used Machinery: A Case Study (ID 103)
Environmental assessment of recycled petroleum and bio based additively manufactured parts via LCA (ID 18)	An empirical investigation into path dependency and embeddedness among sustainable manufacturing capabilities envisaged in the natural resource-based view of the firm (ID 95)	Potential of radar based measuring systems in hot forging (ID 96)	Measurement of Disassembly Work Using Optical Motion Capture (ID 154)
Screening Life Cycle Assessment of Thermoacoustic Panels from Agricultural Byproducts (ID 59)	Empirical Investigation of Climate Neutrality Strategies of Companies in Industrial Production (ID 141)	Evaluation of thermal error compensation strategies regarding their influence on accuracy and energy efficiency of machine tools (ID 114)	Simulation-Based Analysis of (Reverse) Supply Chains in Circular Product-Service-Systems (ID 147)
A Model Calculation of CO_2 Emissions Saving Potential for Fine Blanking of Inductively Heated Sheet Metal with Comparison of the Product Variants (ID 10)	Developing a manufacturing process level framework for green strategies KPIs handling (ID 85)	Investigation of cutting force and surface quality in frozen wood sawing under varying influencing factors to improve the energy- and resource efficiency of sawing processes (ID 153)	Concept of sustainable supply chain management using multi-agent system: Negotiation by linear physical programming (ID 193)
Considering LCA in system architectures of smart-circular PSS (ID 92)	Combining research-, project-, and case-based learning in higher manufacturing engineering education (ID 135)	revolPET®: An innovative "back-to-monomer" recycling technology for the open loop value chain of PET and Polyester composite packaging and textiles (ID 194)	Designing a Reverse Supply Chain Network for Smartphones with Material-Based GHG Emissions and Costs using Linear Physical Programming (ID 160)

Paper Session 5: Sustainable Manufacturing Systems - Life Cycle and Decision Making I
Wed, 5th Oct - 16:00 - 17:30, Room PTZ S001

Framework for Sustainability in Aerospace: A Proof of Concept on Decision Making and Scenario Comparison (ID 188)

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Abstract: Aerospace is a large and growing industry currently dependent on fossil fuels. UK aviation has committed to achieving net zero emissions by 2050. In order for the UK aerospace sector to achieve the sustainability goals, it needs to use the latest technologies while making sure to minimise negative environmental impacts. Ongoing debates claims that the definition of sustainability and its assessment is vague. Companies struggle with quantifying the return on their sustainability investments and necessitate a methodology to aid decision making and quantify improvements against sustainability and profitability. For that reason, this investigation focused on defining a framework to assess sustainability for aerospace manufacturing following a triple bottom line (TBL): profit, people (social responsibility) and planet. The author surveyed a range of major aerospace businesses, including Airbus, BAE Systems, Boeing, GKN, Rolls-Royce and Spirit Aerosystems, who are all industrial partners at the University of Sheffield Advanced Manufacturing Research Centre (AMRC). These businesses are all working together to identify and solve the common challenges associated with sustainable manufacturing and contributed their thoughts to the development of this definition. Collected information has been integrated in a trade study framework that helps scenario comparison and decision making. Discrete Event Simulation (DES) has been used to test the methodology, defining and quantifying alternative scenarios. The framework developed in this study aims to help ensuring that aerospace companies remain profitable whilst also fulfilling the industrial Partners' environmental and societal obligations.

Keywords: Sustainability, Decision Making, Aerospace

Environmental assessment of recycled petroleum and bio based additively manufactured parts via LCA (ID 18)

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Abstract: Additive Manufacturing (AM) as much as sustainability aspects gained increasing attention in the last couple of years. The vision of resource-efficient manufacturing at batch size one is often claimed as an outstanding property of AM. Fused Filament Fabrication, as one of the most used AM technologies, satisfies this statement only in a restricted sense, through simple handling for non-experts and low-cost materials and machines. Next to performance-driven and process-influencing attributes, the question of a general ecological improvement through thermo-mechanical recycling rises. Therefore, recycling options of the thermoplastics are mandatory to explore. Based on the ISO 14040/44 Life Cycle Assessment (LCA) methodology two different geometries were environmentally assessed during a primary process cycle, use phase and recycling. Each geometry was manufactured by a bio-based polymer and internationally produced (PLA) and petroleum-based locally produced polymer (PP) with a corresponding support filament. The methodological approach demonstrates an option how to evaluate the field of AM and recycling regarding environmental aspects. Furthermore, an adaption of the sensitivity towards industrial recycling (material/energy efficiency) showed an ecological benefit.

Keywords: AM, LCA, Thermo-mechanical Recycling, PP, PLA

Screening Life Cycle Assessment of Thermoacoustic Panels from Agricultural Byproducts (ID 59)

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Abstract: The objective of this study was to identify the main environmental impacts of thermoacoustic panels manufactured from agricultural byproducts and thereafter propose measures to improve the environmental performance of this product system. The life cycle assessment (LCA) technique was used to account for the environmental impacts in 10 impact categories. The environmental hotspots were the consumption of electricity at the manufacturing stage, and the use of wheat bran as main input. To improve the environmental performance of the system it was suggested the use of different feedstocks throughout the year, thus accounting for seasonality of agricultural byproducts. Another suggestion was to acquire more energy-efficient equipment, on their own or share the equipment with a partner, or acquire a specific energy mix from the local energy carrier or a third party.

Keywords: LCA, Circular Economy, Circular Bioeconomy, Sustainable Manufacturing, Waste Valorization

A Model Calculation of CO₂ Emissions Saving Potential for Fine Blanking of Inductively Heated Sheet Metal with Comparison of the Product Variants (ID 10)

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Abstract. The steel processing industry must increasingly question itself with regard to environmental aspects, especially for automobile production. As a consequence of the resulting lightweight construction requirements in the automotive sector, manufacturing processes of industrial relevance must deal with high-strength steels. In case of fine blanking, the process faces its limits already when processing medium-high tensile strength steels because of high tool wear or failure. A promising approach to overcome these process limits is the introduction of heat into the processed metal sheet in order to lower the flow stress of the steel. In order to estimate the sustainability of a fine blanking process with inductively heated sheets, the energy input during heating is investigated in this work. An energy balance is drawn for fine blanking of inductively heated sheets. A further component of the work is the subsequent use phase of the components produced in this way. A consideration of the greenhouse gas emissions savings potential by fine blanking in the German automotive production shows possible future perspectives for manufacturing. It could be found that by substituting standard fine blanking process by inductively heated fine blanking of higher strength steels greenhouse gas emissions can be decreased.

Keywords: Fine Blanking, Lightweight Design, Greenhouse gas emissions

Considering LCA in system architectures of smart-circular PSS (ID 92)

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Abstract: The realization of smart-circular Product-Service Systems has theoretically promising advantages compared to traditional products. Nevertheless, the sustainability improvement, especially for the ecological dimension is not yet satisfactorily proved. In this paper, the authors examined the current state of research within a systematic literature review with a specific focus on the overlap of the topics: Life Cycle Assessment, Model-Based Systems Engineering, Product-Service Systems, and Circular Economy. The aim is to analyze the potential of a proactive quantification of the ecological impact in an early stage during the development of smart-circular PSS – the system architecture definition. As a result of the systematic review, 27 relevant papers were identified and analyzed and the findings are presented in a structured way. The main finding is that the current state of the art in this research field still is in the conceptualization stage. In addition, a proactive approach is rare and circularity is not considered to its fullest. Quantified use cases do not draw the system boundaries Cradle-to-Cradle and not every of the 9R-strategies is considered. Furthermore, the potentials and challenges of the revealed research gap are summarized.

Keywords: Circular Economy, Smart Product-Service Systems, Life Cycle Assessment, Model-Based Systems Engineering, System architectures

Paper Session 6: Crosscutting Topics in sustainable Manufacturing - Metrics for Sustainable Manufacturing
Wed, 5th Oct - 16:00 - 17:30, Room PTZ S112

Taxonomy for Biological Transformation principles in the manufacturing industry (ID 133)

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Abstract: Industry and research are seeking answers to current demands in industrial value creation, like resilience of production, sufficient product quality and sustainability of products and processes. A novel line of thought, seeking the accomplishment of those is the Biological Transformation (BT). BT describes the interweaving of biological modes of action, materials and organisms with engineering and information sciences. The conflation of disciplines from natural, technical and social sciences yields in a heterogeneous field of activities with ambiguous technical terms. An ascertainment of principles of BT is required to classify yet undifferentiated patterns in nature-based production, facilitating their systematic implementation in aiming for sustained solutions on current challenges. With increasing research in biomimetic, attempts arise to capture nature-based activities in manufacturing through schematic classifications. Yet, basic semantics representing the effective principles of BT in the manufacturing industry is lacking. The goal of this publication is to introduce a taxonomy of Biological Transformation in manufacturing based on its core principles Bio Inspiration, Bio Integration and Bio Interaction. Within the research project BioFusion 4.0, the taxonomy was developed and applied to classify technology innovations. The paper presents the taxonomy, its development and application in use cases.

Keywords: Biological Transformation, Manufacturing, Sustainability, taxonomy, biomimicry, use cases

An empirical investigation into path dependency and embeddedness among sustainable manufacturing capabilities envisaged in the natural resource-based view of the firm (ID 95)

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Abstract: The seminal and widely cited paper of Hart (1995) on the natural resource-based view of the firm, advocates that the source of competitive advantage in the imminent future will be rooted in emerging sustainable manufacturing capabilities. In order to understand how these capabilities, namely pollution prevention, product stewardship and sustainable development [clean technology] are acquired over period of time, Hart (1995) proposes two competing theories of path dependency and embeddedness. However, there is lack of empirical research on investigation of these two theories. The current study is undertaken to bridge this gap. The paper analyses the available sustainability reports of two multinational firms spanning across a number of years to derive insights on the validity of the two theories. The case observations reveal that the two theories in focus are not necessarily competing in nature but can coexist. The study adds theoretical insights to the literature and provides pointers towards future research directions in the field.

Keywords: Natural Resource Based View, Sustainable Manufacturing Capabilities, Sustainable Manufacturing Practices, Path Dependency, Embeddedness, Pollution Control, Pollution Prevention, Product Stewardship, Clean Technology

Empirical Investigation of Climate Neutrality Strategies of Companies in Industrial Production (ID 141)

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Abstract: The goal of climate neutrality gains importance in the strategic focus of companies. When it comes to strategies for climate neutral production, different companies pursue a variety of approaches. These range from pure compensation approaches to the complete replacement of fossil energy sources. As part of an empirical study, the approaches toward climate neutrality of 50 companies were analyzed. Both small and medium-sized enterprises (SMEs) and large companies were included in the study. Differences already arise from a different understanding of the term climate neutrality. Accordingly, the strategic approaches also differ, both regarding the definition of goals and regarding the specification of a roadmap for achieving those goals. The article presents the results of the empirical study and systematizes the findings.

Keywords: Climate strategies, sustainability, industrial production

Developing a manufacturing process level framework for green strategies KPIs handling (ID 85)

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Abstract: Green strategies in manufacturing have multifold perspectives implying that are highly diversified in terms of resources management. Popular green strategies are Zero Defect, Circularity and Sustainability. The challenges regarding resources efficiency result from different concepts addressed by each strategy; Zero Defect focuses on defect prevention via quality planning, control, and improvement, while Circularity addresses resources optimisation via resources management, material production, usage and disposal. Sustainability is a different approach, to include economic growth and social impact, besides resources management, waste management and environmental impact. Until now, key performance indicators (KPIs) have been used for individual strategy, while literature shows a lack of frameworks towards transforming KPIs when adopting more than one strategy. The current work is a step towards defining an approach describing the relationship between the KPIs of different green strategies and elaborating the repercussions of this transformation on workflows and specifically on manufacturing processes. Two different approaches could be used (monetary and qualitative) with thermoforming used as a case, and the results are indicative of the method efficiency, where KPIs for Zero Defect, Circularity and Sustainability are compared. The framework is developed to be later generalised and applied to other manufacturing processes.

Keywords: KPIs, Green Strategies, Zero Defect Manufacturing, Circularity, Sustainability

Combining research-, project-, and case-based learning in higher manufacturing engineering education (ID 135)

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Abstract: Research in higher manufacturing engineering education must continuously adapt to current and future challenges manufacturing companies are facing. Young engineering students must learn how to design, manage, and implement complex innovation projects. For this purpose, a teaching framework for combining research-, project-, and case-based learning is presented. A proof-of-concept discusses the design, implementation, and evaluation of a master's course at the University of Southern Denmark while following the teaching framework. The evaluation of the students' learning outcomes demonstrates the basic efficacy of the framework. A self-assessment by the students showed a sufficient increase in skills and competencies. The proposed teaching framework can contribute to realizing the Humboldtian idea of integrating research and teaching at universities.

Keywords: Higher engineering education, research-, project-, and case-based learning

Paper Session 7: Sustainable Manufacturing Processes - Machine Tools I
Wed, 5th Oct - 16:00 - 17:30, Room PTZ 001

Influence of additivation of bio-based lubricants on sprayability and solubility for cryogenic minimum quantity lubrication (ID 110)

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Abstract: The development of innovative cooling lubrication strategies is significantly driven by the need to machine materials resistant to high temperatures while taking into account both ecological and economic aspects. Cryogenic minimum quantity lubrication (CMQL) represents a compromise satisfying both efficiency and sustainability in the manufacturing process. A minimal amount of oil is added to the cryogenic medium carbon dioxide (CO_2) to ensure both cooling and lubrication during tool engagement. In this context, vegetable oils, so-called triglycerides, can be used with respect to the cooling lubrication concept. The aim of this paper is to analyze various bio-based oils with regard to their solubility, spraying and flow behavior and to investigate the influence of additives on the performance. During the lubrication tests, the additives have shown no influence on the lubricating effects. Thus the chemical properties of the base oils primarily influence the properties with regard to solubility and spray behavior. Finally, the collected results were correlated with machining tests showing only a limited correlation with the aforementioned lubrication tests.

Keywords: CMQL, milling, liquid carbon dioxide, bio-based lubricants

Potential of radar based measuring systems in hot forging (ID 96)

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Abstract: Hot forging processes and process chains provide components, which meet highest demands due to mechanical properties. A wide range of applications in different industries like oil and gas, automotive and aviation are based on such processes. As those processes are very productive unfavorable process conditions and unnecessary reject or rework are a strong issues and still not solved for industrial scale production. One key challenge is to generate geometrical information of the workpiece. The geometrical characterization of hot forged parts is usually carried out in cold condition resulting in an extensive time delay to processing. Information about the part geometry during processing and right after processing – in hot condition -- is not accessible. An approach to address this are radar based measuring systems. Those systems have specific characteristics like sufficient accuracy and robustness which qualifies them for measuring tasks under rough conditions typically occurring during forging processes. In the paper, different use cases for the application of radar-based measuring systems are identified and analyses based on laboratory scale experiments.

Keywords: radar based measuring system, hot forging, measuring under rough conditions

Evaluation of thermal error compensation strategies regarding their influence on accuracy and energy efficiency of machine tools (ID 114)

Christian Naumann[1], Axel Fickert[2], Lars Penter[1,2], Carola Gißke[3], Eric Wenkler[1,2], Janine Glänzel[1], Philipp Klimant[1,4] and Martin Dix[1,4]

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Abstract. Friction, electrical losses, cooling systems and ambient conditions influence the thermal field of machine tools and cause a significant amount of positioning inaccuracies and production errors. Compensation strategies aim to reduce the thermal error in machine tools. The global urgency for energy-efficient production also affects the selection of specific compensation strategies, especially since some of them consume significant amounts of energy while others are potential energy savers. As of today, there is no method to select the optimal compensation strategy for thermal errors in machine tools. The main reasons are that the quality of any compensation strategy depends heavily on the examined machine tool and its intended usage. Besides this, there are several, often conflicting assessment criteria. This paper provides an overview of existing compensation strategies and presents an evaluation of their effect on the energy consumption. The investigated strategies comprise methods for reducing the heat losses, for decreasing the sensitivity of the tool center point to thermal influences, cooling strategies for removing heat from the machine tool, air conditioning and methods for controllable heat transfer and also various computational methods aimed at predicting and correcting the existing thermal positioning error in the machine tool control. As an addition to previous research, the rating of thermal error compensation strategies was extended by their effect on energy efficiency. The authors demonstrate that accuracy and energy efficiency must be considered jointly for each individual machine tool and manufacturing task.

Keywords: Machine Tool, Thermal Error, Error Compensation, Energy Consumption, Efficiency, Effectiveness

Investigation of cutting force and surface quality in frozen wood sawing under varying influencing factors to improve the energy- and resource efficiency of sawing processes (ID 153)

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Abstract: Wood as a renewable material plays an important role in transforming society towards sustainability and climate neutrality. However, wood is a difficult material to saw due to its anisotropic and inhomogeneous properties. Currently, the adaption of process parameters due to varying wood temperature and moisture content are solely based on operator experience. This frequently results in unfavorable settings of process parameters leading to a drastic increase in energy consumption and poor surface quality of the sawn wood. This paper investigates the cutting force when sawing frozen spruce wood with a two tooth research saw blade and the surface quality of the resulting wood samples under varying influencing factors. The material properties temperature between 20 °C and -40 °C and moisture content as well as the kinematic factor cutting direction were observed. The results show that the cutting force of moist and wet wood increase with decreasing temperature and remain constant for dry wood. Additionally, the surface quality of wet and dry wood samples is improved when sawing wood with lower temperature values. Using these results, the operator can be supported by a data driven approach for the adaption of machining parameters, hence improving the energy- and resource-efficiency of the process.

Keywords: frozen spruce wood, wood sawing, cutting force, surface quality, frozen wood, temperature, moisture content, cutting direction

revolPET®: An innovative "back-to-monomer" recycling technology for the open loop value chain of PET and Polyester composite packaging and textiles (ID 194)

Renan Louro Cardoso Franco[1]; Carsten Eichert[1]; Charlotte Lücking[1,2]; Lars Biermann[1,2]; Mandy Paschetag[2]; Stephan Scholl[2]

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Abstract: Nowadays there is a need for innovative solutions for composite materials in the packaging and textile sectors. These are formed by multilayer structures that improve technical performance however complicates recycling. Consequently, they are mostly sent to energy recovery or downgrade recycling processes. To avoid this, new recycling technologies are needed. The innovative "back-to-monomer" recycling technology "revolPET®" represents a solution for this challenge. In the process, the polyethylene terephthalate (PET) is selectively depolymerized to recover the monomers ethylene glycol (EG) and terephthalic acid (TA) for a new PET production. By an alkaline hydrolysis, the PET reacts continuously with a strong base in a twin-screw extruder. The average residence time in the extruder is less than one minute with a process yield up to 95 %. Due to the mild depolymerization conditions, the other polymers remain chemically unchanged and can be easily separated. The produced monomers are regained in virgin quality and can achieve a 33 % reduction on the greenhouse gases emissions if compared with the crude oil production route. In this contribution, the technology on a pilot scale as well as the results of the first scale-up investigations are presented and discussed with respect to technical maturity and environmental benefit.

Keywords: PET, recycling, depolymerization, circular economy, sustainability

Paper Session 8: Sustainable Manufacturing Processes - Supply Chain and Remanufacturing Processes II
Wed, 5th Oct - 16:00 - 17:30, Virtual Session

Analysis of Elementary Technology Considering the Remanufacturing of Used Machinery: A Case Study (ID 103)

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Abstract: Globally, the circular economy is emerging as a key issue for industrial innovation by enhancing the efficiency of resource use and promoting resource circulation. Remanufacturing is to recover the product after use to maintain its original performance through a series of production processes. Machine tools experience various operational problems such as malfunction, damage to parts, and deterioration after the service life has elapsed. Remanufacturing technology has several common technologies that can solve similar failures among different items, and can be largely divided into existing remanufacturing process technology and technology for upgrading the performance of a machine. A systematic technical background is needed to ensure the performance and reliability of remanufacturing products, but so far there are few cases of research on machine tool remanufacturing in Korea. Therefore, in this study, machinery items with high frequency of use and marketability among machine tools were reviewed as targets for remanufacturing. For the remanufacturing of used machine tools, failures to be solved by functional characteristics of target parts were identified, and remanufacturing elementary technologies were classified and analyzed, respectively. In addition, basic studies such as major performance, Failure Mode and Effect Analysis (FMEA) were conducted for the used machine tools.

Keywords: Remanufacturing, Machinery, Machine Tool, Failure Mode and Effect Analysis

Measurement of Disassembly Work Using Optical Motion Capture (ID 154)

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Abstract: In recent years, the depletion of natural resources has been severe globally. One of the solutions to this problem is to reuse and recycle materials from end-of-life (EOL) products and reduce waste. In the industrial field, disassembly work is needed to take back parts/materials from the end-of-life assembly products. Furthermore, in the manufacturing industry, there are human resource development or skill transfer issues due to a declining birth rate and an aging population as well as a labor shortage in developed countries. In particular, in Japan, the population aged 65 and overreached 28.8% of the total population in 2019, and the labor shortage has become more serious. To resolve these issues, the digitization of skills through optical motion capture is promoted in this industry, where three-dimensional coordinate data of workers can be accurately measured. Toshiba Corporation has introduced motion capture for achieving more effective guidance and skill transfer at the work site. However, data related to disassembly were not obtained via motion capture. This study

measures and analyzes the motion data for disassembly work obtained via optical motion capture. First, the motion data for disassembly work is obtained via optical motion capture. Next, the data obtained is shown graphically and compared by body part. Finally, the results are shown and discussed.

Keywords: Sustainable Manufacturing, Reuse and Recycling, Work Analysis, Motion Tracking, Digital Transformation

Simulation-Based Analysis of (Reverse) Supply Chains in Circular Product-Service-Systems (ID 147)

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Abstract: With an expected growth of global waste to 3.40 billion tonnes by 2050 and a circularity today of only 8.6% of the world, the earth's sustainable resources are being exploited beyond their regeneration capacity. Hence, it is necessary to step away from a take – make – dispose principal and transform from a linear towards a circular economy to close product cycles to optimize resource consumption and reduce waste. Product-Service-Systems (PSSs), based on multiple product life cycles combined with remanufacturing, offer a solution to close product cycles. In such PSS, the responsibility for returning, remanufacturing, and repairing used products remains with the Original Equipment Manufacturer (OEM) and increases its need in (reverse) supply chain activities. Essential factors for (reverse) supply chains are, e.g., determining the distribution network, the location of recovery facilities, the geographical dispersion of the customers, and the information flows between the different stakeholders. In this context, this work proposes a multi-method simulation model to support practitioners in determining the optimal infrastructure for storing, remanufacturing, and repairing the used products regarding economic and ecological target criteria. The applicability of the proposed approach is illustrated through a case study of a white goods manufacturing company. This case study highlights the importance of determining the optimal infrastructure in a (reverse) supply chain in PSS business models.

Keywords: Circular Economy, Product-Service-Systems, Simulation, Facility Location Problem

Concept of sustainable supply chain management using multi-agent system: Negotiation by linear physical programming (ID 193)

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Abstract: Industry and academia are both making efforts to realize a sustainable society; an important part of these efforts is to ensure the sustainability of the supply chains that support our daily life. Sustainable supply chains are more complex than traditional supply chains, and they involve a combination of multiple issues. Multiple plans must be used to deal with these issues. However, these plans often conflict with each other. To manage a sustainable supply chain, an integrated approach is needed to operate multiple plans for multiple issues. This paper introduces a research concept for integrated sustainable supply chain management using a multi-agent system. An agent executing a plan for an issue autonomously negotiates with other agents and avoids conflicts. Linear physical programming used for negotiation balances agents' utility and ensures that all plans function well. Through this research, we provide an example of the simultaneous operation of multiple plans in a sustainable supply chain, aiming at the social implementation of sustainable supply chains.

Keywords: Research concept, Decision making, Linear physical programming, Negotiation process

Designing a Reverse Supply Chain Network for Smartphones with Material-Based GHG Emissions and Costs using Linear Physical Programming (ID 160)

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Abstract: Currently, levels of production and disposal for communication devices such as smartphones are continuing to increase. In the life cycle of a smartphone, the majority of greenhouse gas (GHG) emissions are generated in the material production stage. To recover the GHG emissions from end-of-life (EOL) products such as smartphones, manufacturers have to recycle EOL products. However, smartphones on the market undergo little recycling because costs related to recycling, transportation, and facilities are too high. Therefore, the decision maker (DM) has to design a reverse supply chain network for collecting EOL products from users and transporting them to recovery or disposal facilities that is not only environmentally friendly but also economically feasible. This study applies a bi-objective reverse supply chain network design to GHG volumes and related costs applying a multi-criteria decision-making methods linear physical programming (LPP) to design a reverse supply chain network the case of smartphones. First, the reverse supply chain network is modeled for recycling EOL smartphones, and a case study based on literatures and Life Cycle Assessment are prepared. Next, the objective functions are set and formulated to minimize the total volume of GHG emissions and the total cost using LPP and integer programming. Finally, numerical experiments on the reverse supply chain are conducted and evaluated.

Keywords: Reverse Logistics, Carbon Recovery, Multi-Criteria Decision Making, Life Cycle Assessment, Recycling

Thu, 6th October - 10:30 - 13:30			
Paper Session 9 Sustainable Manufacturing Systems - **Production Planning, Scheduling and Control**	**Paper Session 10** Sustainable Manufacturing Processes - **Materials**	**Paper Session 11** Sustainable Manufacturing Processes - **Additive Manufacturing**	
Room PTZ S001	Room PTZ S112	Room PTZ 001	
Waste Minimization by Inventory Management in High-Volume High-Complexity Manufacturing Organizations (ID 31)	Towards making polymer food packaging suitable for the circular economy: Cleanliness is next to godliness (ID 116)	Potential analysis for the use of bio-based plastics with natural fiber reinforcement in additive manufacturing (ID 8)	
Cascaded Scheduling for Highly Autonomous Production Cells with AGVs (ID 12)	CO_2 footprint of machine elements made of fiber-rein-forced polymer concrete compared to steel components (ID 55)	Development of magnetic sheets for CO_2 efficient electric drives using an additive manufacturing approach (ID 35)	
A model to balance production workload distribution in a trailer manufacturing organisation under fluctuating customer ordering condition (ID 109)	Evaluation of material properties of spruce wood samples to improve the development process for more sustainable sawing processes (ID 139)	Towards a comparative index assessing mechanical performance, material consumption and energy requirements for additive manufactured parts (ID 129)	
Enabling Sustainable Consumption: Development of an Inventory Management Tool for Food Recovery (ID 184)	Liquid desiccant dehumidification systems: Jet cross-talking effect in multi-electrosprays (ID 22)	A framework to compute carbon emissions generated from additive manufacturing processes (ID 84)	
Resource-efficient process chains for the production of high-performance powertrain components in the automotive industry (ID 124)	High Strength and Electrical Conductivity of α-Al-CNTs+GAgNPs Nanocomposites (ID 149)	Competencies to address the industrial additive manufacturing towards sustainable production (ID 155)	
Optimizing Product Life Cycle Systems for Manufacturing in a Circular Economy (ID 186)	Material recycling of end-of-life tires: The influence of recyclates on the processing of rubber compounds (ID 68)	Modeling Carbon Border Tax for Material-based GHG Emission and Costs in Global Supply Chain Network (ID 126)	

Paper Session 9: Sustainable Manufacturing Systems - Production Planning, Scheduling and Control
Thu, 6th Oct - 10:30 - 13:30, Room PTZ S001

Waste Minimization by Inventory Management in High-Volume High-Complexity Manufacturing Organizations (ID 31)

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Abstract: Organizations that manufacture high volumes of complex products (e.g., pharmaceutical, automotive, food) require specific strategies to ensure efficient processing of parts and a sustainable level of inventory by waste minimization. A review of literature sources revealed how inventory is classified and managed amongst organizations and industries and key challenges that current organizations face with existing inventory management systems. In this paper, these findings are compared against each other to determine best practices and potential shortfalls that should be addressed when trying to manage inventory holistically. A study is then conducted using qualitative data from 15 semi-structured interviews to answer key questions on inventory management based on the findings from the literature survey. Responses are inductively coded and analyzed to reveal the most important factors of inventory management and determine the most prominent themes. A graphical model to represent the findings is also presented. Inventory functional accountability, inventory classification, operational strategies, visual management of inventory data, and efficient processes were some of the key themes known to be critical for effective inventory management and thus illustrated in the graphical model.

Keywords: Inventory Management, Sustainability, High Volume, High Complexity

Cascaded Scheduling for Highly Autonomous Production Cells with AGVs (ID 12)

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Abstract: Highly autonomous production cells are a crucial part of manufacturing systems in industry 4.0 and can contribute to a sustainable value-adding process. To realize a high degree of autonomy in production cells with an industrial robot and a machine tool, an experimental approach was carried out to deal with numerous challenges on various automation levels. One crucial aspect is the scheduling problem of tasks for each resource (machine tool, tools, robot, AGV) depending on various data needed for a job-shop scheduling algorithm. The findings show that the necessary data has to be derived from different automation levels in a company: horizontally from ERP to shop-floor, vertically from the order handling department to the maintenance department. Utilizing that data, the contribution provides a cascaded scheduling approach for machine tool jobs as well as CNC and robot tasks for highly autonomous production cells supplied by AGVs.

Keywords: robot, scheduling, optimization, algorithm

A model to balance production workload distribution in a trailer manufacturing organisation under fluctuating customer ordering condition (ID 109)

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Abstract: Trailer manufacturing organisation considered in this study is currently experiencing a high volume of backlog orders due to its poor balancing of production workload distribution during capacity planning and scheduling. This issue has resulted in loss of sales orders experienced by the trailer manufacturing organisation. In light of this, this research study developed a model that could be used to balance production workload distribution that could be used to timeously meet varying customer orders as well as drastically minimise the backlog cost experienced in a trailer manufacturing organisation. To achieve this, on the one hand, a system model of the current production workload distribution used at this trailer manufacturing organisation was developed using AnyLogic software and parametrized using the manufacturing system operation operating conditions obtained via system observation for a period of three (3) months, in order to identify the bottleneck stations and inefficiencies present within this organisation. On the other hand, design of experiments, equipped with feasible workload control strategies were conducted on the model. The result of the simulated model revealed that the usage of an additional two bending machines and two primer paint workers, usage of additional three laser machines and three treatment workers, Heijunka order dispatching principle and Constant Work-In-Process (ConWIP) will increase the service level and mean machine capacity utilisation of the organisation, as well as reduce the backlog cost, opportunity cost and average order lead time.

Keywords: Workload Distribution, Heijunka, ConWIP, Backlog Orders

Enabling Sustainable Consumption: Development of an Inventory Management Tool for Food Recovery (ID 184)

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Abstract. The food supply chain presents numerous challenges from farm to fork resulting in over one third of all food produced going to waste. These challenges uniquely affect the level of food insecurity among regional populations. Food lost in the production and manufacturing stages of the supply chain are most influential in developing nations. Meanwhile the retail and consumer stages substantially affect food wasted in developed nations. The project described in this paper applies a systems-based approach to evaluate the inventory management needs for a charitable food recovery organization (FRO) and develop a tool for more effective management of recovered food. The capabilities to be incorporated in the tool are identified through an in-depth literature review and a current state assessment of the FRO's system. Influential relationships and feedback loops are examined to provide a central view of inventory assets, how they are acquired and dispersed. The easy-to-use tool is then developed to interface with existing data collection mechanisms at the FRO. The paper will detail the research involved and necessary steps taken to provide accurate sustainability and inventory reporting for the FRO for more effective food recovery. Limitations of the tool and potential improvement opportunities will also be discussed.

Keywords: Food Waste Recovery, Inventory Management, and Sustainability Reporting

Resource-efficient process chains for the production of high-performance powertrain components in the automotive industry (ID 124)

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Abstract: This paper focuses on process chains for power train components of passenger cars and heavy duty vehicles. In the project "Powertrain 2025" particular attention is being paid to increase the resource efficiency of the manufacturing process chains and reduce energy demand during service life. In detail cylinder liners are equipped with an adapted geometry and topography which reduces friction losses. Process chains for chassis components are investigated and optimized in order to increase the resource efficiency during manufacturing, service life and maintenance. In addition, process chains for the manufacturing of drive shafts are adjusted. By eliminating hard machining, energy is saved and friction losses are reduced by laser machining of microstructures. Furthermore, micro dimples are applied in vane pumps, which leads to a tribological improvement and thus enhances their friction behaviour. Moreover, a system architecture for process planning is developed and ecologically optimized process parameters are calculated. For a final consideration, a calculation software is developed which enables to calculate the main energy consumption of the manufacturing processes and the carbon footprint for the expected service life. A weight reduction of the powertrain components of 4.5 kg per vehicle and a potential annual energy saving of 13,073 MWh is obtained.

Keywords: Resource Efficiency, Automotive Industry, Process Chains

Optimizing Product Life Cycle Systems for Manufacturing in a Circular Economy (ID 186)

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Abstract: Global population growth and increasing resource scarcity are necessitating sustainable manufacturing and circular economy (CE) practices. These practices require the decisions made at each product life cycle (PLC) stage consider sustainability and circularity implications. We propose PLC system level optimization to identify the most favorable choices, instead of siloed individual PLC stage-specific optimizations. This should yield better circularity by permitting manufacturers to take a more holistic view and identify the areas of highest impact across the PLC. This paper presents initial work towards building a PLC system optimization framework. From an initial review of current circularity metrics, we identify metrics that are suitable for forming the optimization objectives. Second, we identify decision variables available to manufacturers across the PLC that are useful in optimizing the entire system's circularity and sustainability. Finally, we identify limitations of current metrics, and discuss major challenges and potential solutions to PLC system optimization problems.

Keywords: Circular economy, Sustainable manufacturing, Optimization, Metrics, Product life cycle

Paper Session 10: Sustainable Manufacturing Processes - Materials
Thu, 6th Oct - 10:30 - 13:30, Room PTZ S112

Towards making polymer food packaging suitable for the circular economy: Cleanliness is next to godliness (ID 116)

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Abstract: Single use plastic packaging and its environmental impacts have received much attention over the last few years from governments, businesses and consumers. One option to reduce plastic packaging waste and its associated environmental impacts is to shift towards circular business models, supplying reusable packaging options that are used many times before being recycled. One technical barrier to the implementation of plastic food packaging reuse is the need to effectively clean the packs and provide cleaning assurance to prevent the possibility of product crossover. This research investigated the feasibility of using Ultraviolet Fluorescence imaging to optically detect residual food fouling and thus assuring cleanliness in the case example of margarine spread tubs. Processing of obtained images was carried out using MATLAB® applying Otsu's thresholding method. It was established that for the current setup the minimum detectable quantity of fouling was of the order 10^{-4} g/mm2. The assessment process was correlated against that of Adenosine Triphosphate assay, an industry-standard process for assessing the cleanliness of food contact surfaces. The implications of the investigated technique overcome one barrier to plastic food packaging reuse on an industrial scale. Fast and reliable fouling evaluation of every pack will underpin business and consumer trust in such a circular material flow. The established technique has the potential to form part of the wider reuse system for polymer packaging. Implications on optical detection optimization, packaging design, and suitability for automation are discussed alongside wider food supply chain considerations.

Keywords: Plastic waste, product reuse, circular supply chains, quality assurance, ultraviolet fluorescence imaging, optical sensors

CO2 footprint of machine elements made of fiber-rein-forced polymer concrete compared to steel components (ID 55)

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Abstract: Energy efficiency and resource economizing are the drivers for the development of new types of material-hybrid design approaches for machine tools. Polymer concrete has been used for machine beds in machine tool design for many years. The good thermal and dynamic properties of the material are particularly convincing in this context. The good damping properties for structural components are also interesting, as this reduces for example tool wear and at the same time the high damping compared to steel structures has a positive effect on the surface quality of the machined workpiece. Current research in the field of structural dynamics is dealing with the substitution of steel and cast components with hybrid, actively preloaded polymer concrete parts. This allows the use of

the positive damping properties of polymer concrete and the positive tensile strengths of the integrated fiber-reinforced structures for dynamically loaded machine components such as machine arms or machine stands. The focus of the study is to replace the arm of a bed-type milling machine, which is currently a welded design, with a component made of prestressed carbon fiber-reinforced polymer concrete. Based on the first results of the volume ratios of the structures, conclusions are drawn about the life cycle assessment (cradle to gate) of the components. The results will contribute to a design recommendation for the carbon fiber reinforcement in the polymer concrete arm to achieve a better structural efficiency on the one hand and a better life cycle assessment on the other.

Keywords: CO2 emission, Composite materials, Design optimization

Evaluation of material properties of spruce wood samples to improve the development process for more sustainable sawing processes (ID 139)

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Abstract: The processing of wood as a renewable and sustainable material is steadily gaining in importance. However, sawing processes in sawmills are characterized by high electrical energy consumption. Improving the geometry of the saw teeth is an option to make sawing processes more energy efficient and sustainable. Since the industrial sawing processes in sawmills are rather inflexible, the development of new saw tooth geometries takes place in smaller experimental setups. However, the inhomogeneous and anisotropic properties of wood make it difficult to compare different material samples and saw teeth on the basis of measured values. This leads to untapped potentials regarding energy efficiency and sustainability in industrial sawing processes. This paper discusses material properties of spruce wood samples, depending on their place of extraction from the tree trunk. The measured variables considered are the wood moisture content, strength properties and the cutting force occurring during the sawing process. The results show that the measured values vary to different degrees within a tree trunk and between different tree trunks. Based on the results the validity of comparison measurements in the tool development process can be improved and thus increase the efficiency and sustainability of industrial sawing processes.

Keywords: sawing, material properties, wood

Liquid desiccant dehumidification systems: Jet cross-talking effect in multi-electrosprays (ID 22)

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Abstract. When liquid desiccant systems are employed to dehumidify air electrospraying technique helps to increase the surface area of the liquid. Multiplexing of the jets by introducing several emitters for increased efficiency is commendable but, there is a tendency of the jets to cross talk with each other due to electrical shielding. Cross talking of jets will result in the failure of the jets to break properly into droplets for effective dehumidification. This piece of work analyzed the conditions for electrical shielding among jets which results in efficient electrospray. To evaluate how cross talking affects multiple emitter nozzles, the mathematical model was built by superimposing the electric potentials of one emitter in an array of emitters. A Computational Fluid Dynamics simulation model was developed to investigate the conditions for electrical shielding among jets during electrospray process with glycerol as the working substance. In flow modelling, Ansys Fluent with Volume of Fluid and the Taylor Dielectric model were involved. The flow rate that guarantees stability in the electrospray was determined together with the optimum voltage resulting in a spray current which reduces electrical shielding. An analysis on the electrical conductivity of the liquid to ensure stability and efficiency in electrospray was done. The pressure contours of the nozzle were determined together with velocity of the desiccant against density. Emitter spacing, applied voltage, flow rate and the electrical conductivity plays a pivotal role on the prevention of cross talking of jets during the electrospraying process.

Keywords: Electrospray, Multiple Emitters, Electrical Shielding, CFD Model

High Strength and Electrical Conductivity of α-Al-CNTs+GAgNPs Nanocomposites (ID 149)

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Abstract: The development of sustainable α-Al-carbon nanotubes (CNTs) using sustainable manufacturing green synthesis silver nanoparticles (GAgNPs) superconductor nanocomposites was studied. Sustainable green synthesis silver nanoparticles (GAgNPs) were used for the decoration of CNTS. The composites were made by modified sustainable manufacturing spark plasma sintering (SPS). The microstructure, strength, and electrical conductivity of the nanocomposites were determined. The formation of sub-grain in the Al-4%CNTs+2%GAg.NPs composite generates more dislocation density. The electrical conductivity of Al, Al-4%CNTs and Al-4%CNTs+2%GAgNPs composites is increased by 7.8% and 93.11%, respectively. An 82.14% enhancement in tensile strength was recorded at Al-4%CNTs+2%GAgNPs over pure Al. High sustainable tension conductor applications can be made with these materials since the values of strength and factor of safety are within the recommended standard.

Keywords: Cashew leaves; electrical conductivity; strength; stress analysis; and microstructure

Material recycling of end-of-life tires: The influence of recyclates on the processing of rubber compounds (ID 68)

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Abstract: The paper focuses on the recycling of end-of-life tires (ELTs) by ad-mixing ELT recyclates to rubber compounds. It deals with the physical and chemical interactions resulting from the admixture of finely ground powder from end-of-life tires to a sulfur-cured rubber compound. Using exemplary rubber recipes, the effects of viscosity increase, accelerated crosslinking and stiffness decrease are quantified and the underlying reasons are explained.

Keywords: circular economy, elastomer, sulphur migration, accelerated scorch

Paper Session 11: Sustainable Manufacturing Processes - Additive Manufacturing
Thu, 6th Oct - 10:30 - 13:30, Room PTZ 001

Potential analysis for the use of bio-based plastics with natural fiber reinforcement in additive manufacturing (ID 8)

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Abstract: Plastics are used today in many areas of the automotive, aerospace and mechanical engineering industries due to their lightweight potential and ease of processing. Additive manufacturing is applied more and more frequently, as it offers a high degree of design freedom and eliminates the need for complex tools. However, the application of additively manufactured components made of plastics have so far been limited due to their comparatively low strength. For this reason, processes that offer additional reinforcement of the plastic matrix using fibers made of high-strength materials have been developed. However, these components represent a composite of different materials produced on the basis of fossil raw materials, which are difficult to recycle and generally not biodegradable. Therefore, this paper will explore the potential for new composite materials whose matrix consists of a bio-based plastic. In this investigation, it is assumed that the matrix is reinforced with a fibrous material made of natural fiber to significantly increase the strength. This potential material should offer a lightweight yet strong structure and be biodegradable after use under controlled conditions. Therefore, the state of the art in the use of bio-based materials in 3D printing is first presented. In order to determine the economic boundary conditions, the growth potentials for bio-based materials are analyzed. Also, the recycling prospects for bio-based plastics will also be highlighted. The greenhouse gas emissions and land use to be expected when using bio-based materials are also estimated. Finally, the degradability of the composites is discussed.

Keywords: Additive manufacturing, Fiber reinforcement, Natural fibers, Degradability, bio-based plastics.

Development of magnetic sheets for CO2 efficient electric drives using an additive manufacturing approach (ID 35)

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Abstract: Climate change and its negative consequences for the environment are the greatest challenge of the current era. Electric machines are considered key both for the generation of regenerative electricity and as a substitute for fossil fuels in industry and fossil engines in the transportation sector. Resource-efficient manufacturing and operation of electric machines are therefore of high importance. The central component of every electric machine is the soft magnetic core. The manufacturing process and material selection are influencing the iron losses during operation. This paper presents a novel technology for manufacturing magnetic sheets and lamination cores for carbon dioxide efficient electric drives using an additive manufacturing approach. The potential of the technology is explained and the challenges in process development are highlighted.

Keywords: Additive Manufacturing, Magnetic Sheets, Electrical Steel, Sustainable Manufacturing, Electric Motor, New materials

Towards a comparative index assessing mechanical performance, material consumption and energy requirements for additive manufactured parts (ID 129)

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Abstract: The increasing use of Additive Manufacturing technologies and systems in several industrial sectors and their numerous applications turn the attention of scientists and investigators to studying and evaluating the environmental impacts of these processes. Additive Manufacturing generally allows for a reduction of raw material consumption and waste generation. On the other hand, the need for long processing times and the necessary thermal conditioning of the manufacturing chamber to avoid product defects, lead to a considerable amount of consumed energy per produced item. Energy consumption has been a primary concern of the research on the sustainability of Additive Manufacturing indeed. More recent studies extended the analysis through more complete evaluation methods such as the Life Cycle Assessment. This approach allows a detailed description of environmental impacts but is affected by some concerns about the need for an interpretation of the final results, which can be non-univocal. This fact is particularly critical when the assessment is intended to be used for comparison between alternative solutions. In this study, a novel index is introduced including three main aspects: material consumption, energy requirements and mechanical performance. The proposed formulation makes the index immediately usable for comparing alternative solutions. Within the scope of this study, the index has been applied to one of the most widespread Additive Manufacturing processes, namely Fused Filament Fabrication. The presented case study demonstrates the suitability of the proposed method to compare and identify the optimal choice among alternative manufacturing scenarios.

Keywords: Additive Manufacturing, Fused Filament Fabrication, Energy Consumption, Life Cycle Assessment, Performance Index

A framework to compute carbon emissions generated from additive manufacturing processes (ID 84)

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Abstract: Additive Manufacturing (AM) is an emerging and promising technology increasingly adopted from Industry. However, Industry is responsible for the majority of global carbon emissions (CEs), heavily contributing to greenhouse effect. Therefore, it is important to define the environmental impact of all processes, including AM carbon footprint. This work aims at reviewing literature for the equations for CE calculations of AM and developing a framework for CEs calculations generated from all the types of AM. Literature was found for some AM types, with each type of AM described stepwise and categorized per Process, Machine and System level. At each step, the equations for CEs, based on carbon emission factor and energy spent, were allocated. At process level, CEs come exclusively from the energy spent for curing. At the machine level, CEs are related to the process, auxiliary equipment and consumables. At system level, additional CEs are derived from material used, pre-processing and post-processing steps. Total carbon emissions are the sum of CEs at machine level and additional CEs from system level. Generalization of this approach led to a framework that can be used for all types of AM, to calculate CEs of each AM type based on the steps included.

Keywords: Additive Manufacturing, Carbon Emission Calculation, Carbon Footprint

Competencies to address the industrial additive manufacturing towards sustainable production (ID 155)

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Abstract: Since the North Rhine-Westphalia (NRW) region is currently undergoing a structural change towards a CO2 neutral energy supply, the use of additive manufacturing (AM) can offer great potential to produce in a more sustainable way. AM can also offer opportunities for industry with regard to other aspects, since production complexity can also be reduced, and time-to-market shortened at the same time. Against this background of increasing importance of AM, this study has the focus to find out what competencies an employee in AM should have in order to establish him/herself in this area in the future and successfully use AM in the industry. For this purpose, problem-centered and guided expert interviews were conducted with 19 experts from different industries. The interviews were then transcribed and evaluated using Mayring's content analysis. A key finding of this work is that knowledge of technology and materials, the ability to part identification, and a basic understanding of the process chain in AM are among the most important hard skills for a future employee in AM. Regarding soft skills, the willingness to openly exchange ideas, the ability to work in a team in conjunction with good communication skills, a conscientious approach to work and the right mindset are emphasized. In conclusion, regarding structural change in NRW, it is clear from the interviews that the experts particularly suggest opportunities in the area of sustainability, but also greater collaboration within companies and universities involved in AM.

Keywords: Additive Manufacturing, Sustainable production, Competencies, Upskilling and Reskilling

Modeling Carbon Border Tax for Material-based GHG Emission and Costs in Global Supply Chain Network (ID 126)

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Abstract: One of the problems in an environmental policy is carbon leakage, which is increasing Greenhouse Gas (GHG) emissions as an adverse effect due to the production shift from countries with strict climate change policies to those with careless ones. In this situation, carbon boarder adjustment (CBA) is considered as a countermeasure for mitigating GHG emission and carbon leakage globally, with European Union (EU) agreeing to introduce the CBA in 2026. CBA is expected to have huge impact upon a global supply chain network. The reasons of it are that total cost and GHG emissions on a global supply chain network have been influenced by the different procurement cost, customs duty and GHG level from each country by the price level, the governmental policy, and the energy mix. However, it is not revealed how much effect CBA has for the cost, and GHG emission on a global supply chain network. Thus, this study models a global supply chain network with CBA as the intersection of environment and economy. First, a global supply chain network with CBA is modeled and formulated for minimizing the total cost using integer programming. Second, a problem example is prepared with bill of materials for the procurement cost and the GHG emission using life cycle assessment. After there, under the market in the U.S., a numerical experiment is conducted to validate the proposed model. Finally, the effect of CBA is discussed.

Keywords: Carbon Border Adjustment Mechanism, Carbon Leakage, Trans Pacific Partnership, Integer Programming, Life Cycle Assessme

Thu, 6th October - 14:00 - 15:30

Paper Session 12 Sustainable Manufacturing Systems - **Energy Efficiency II**	Paper Session 13 Sustainable Manufacturing Processes - **Manufacturing Processes**	Paper Session 14 Sustainable Manufacturing Processes - **Machine Tools II**	Paper Session 15 Sustainable Manufacturing Systems - **Production Systems I**
Room PTZ S001	Room PTZ S112	Room PTZ 001	Virtual Session
User-centric Energy Efficiency Optimization for Machining (ID 56)	3D-printed MWF nozzles for improved energy efficiency and performance during grinding (ID 107)	Development of a Pneumatic Clamping System with Position and Force Control Machining (ID 175)	Integrating lean management principles into human-robot collaboration in disassembly cell (ID 57)
Load Profile Optimization using Electricity Wholesale Market Price Data for Discrete Manufacturing (ID 66)	Model-based Correlation Analysis of Machine Control Parameters and Process Vibration Amplitudes by the Example of Milling (ID 30)	Initial Period of Chip Formation: Observations towards Enhancing Machining Sustainability (ID 60)	A Mathematical Model considering Multi-Skilled Operators and Industrial Robots on Reconfigurable Manufacturing Cells (ID 112)
Method for evaluating and identifying energy-efficient process chains for the manufacturing of press hardening tools based on the Deming Circle (ID 33)	A Comparative Sustainability Assessment of Cutting Fluids Usage in Band Sawing (ID 195)	Influence of carbon dioxide temperature on sprayability and solubility in cryogenic minimum quantity lubrication with bio-based lubricants (ID 111)	5S Implementation to Minimize Waste in Bread Production Process (Case Study: Madani Bakery) (ID 14)
Approach for Design of Low Carbon Footprint Paint Shops in the Automotive Industry (ID 73)	Design and characterization of piezoceramic thick film sensor for measuring cutting forces in turning processes (ID 206)	Sustainability Enhancement of the Coal based Direct Reduction of Iron premised on a Rotary Kiln (ID 180)	Environmental Assessment and Optimization when Machining with Micro-Textured Cutting Tools (ID 74)
A Practical Approach to Realize a Closed Loop Energy Demand Optimization of Milling Machine Tools in Series Production (ID 17)	The costs of more sustainable castings. Can we afford the change? (ID 86)	The Influence of the Rake Angle on the Cutting of Low-Lead and Lead-Free Brass Alloys (ID 98)	

Paper Session 12: Sustainable Manufacturing Systems - Energy Efficiency II
Thu, 6th Oct - 14:00 - 15:30, Room PTZ S001

User-centric Energy Efficiency Optimization for Machining (ID 56)

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Abstract: A user-centric end-to-end machining optimization approach for increased energy efficiency according to the major goal of carbon free production, is presented. By doing so the two major challenges for medium size companies get addressed. First data acquisition with sensors, which only require minimum investment cost by using machine-internal measured values and additional machine parameters. On example applications, it is shown how this combination enables transformation from parameter based to tool load based optimization. This foundation ensures the continuous selection of the process window with highest performance effectiveness of machine tool and cutting tool, regardless if machining anomalies occur. Second a collaborative assistance system, which provides to the machine operator the option for input his specific experience and knowledge, thus making personal contribution to energy savings tangible. Thereby the carbon footprint per manufactured product component gets minimized.

Keywords: Energy efficiency, Process optimization, Torque measurement, Internal machine data, Machine calibration, Data visualization, Human-machine interface

Load Profile Optimization using Electricity Wholesale Market Price Data for Discrete Manufacturing (ID 66)

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Abstract: Several strategies for reducing energy costs can be derived from the energy procurement cost function for Austrian end users of electrical energy. Based on short-term energy procurement on the day-ahead trading floor an optimization problem for cost-optimal scheduling of the load curve of a single plant has been formulated. A preliminary study for an annealing furnace is presented and it is found that the approach can lead to significant savings during periods of volatile prices. Furthermore, the strategy is applicable to any production process that provides sufficient flexibility, and therefore, if the trade-off between peak energy costs is included, can be applied to entire production systems.

Keywords: energy flexibility; demand side management; demand response; energy price volatility; day-ahead; energy-cost-optimization

Method for evaluating and identifying energy-efficient process chains for the manufacturing of press hardening tools based on the Deming Circle (ID 33)

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Abstract: In response to rising energy demand, climate change and resource scarcity, the German government has set guiding targets for the transformation of energy systems by 2050. One goal is to increase energy efficiency in order to halve the demand for energy. An important instrument for increasing energy efficiency and reducing energy costs is the energy audit. By determining how much energy is consumed in which areas of the company, it is possible to identify where there is potential for savings. This paper presents an evaluation method for identifying energy-efficient process chains for the production of press hardening tools. The evaluation method is based on the Deming Circle and is intended to serve as a supporting tool for the energy audit. The method enables the analysis and evaluation of energetic variables of a process chain and is designed for manufacturing companies.

Keywords: Energy Management System, Energy consumption, (PDCA) cycle

Approach for Design of Low Carbon Footprint Paint Shops in the Automotive Industry (ID 73)

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Abstract: To mitigate the ongoing progress of climate change, the European Commission announced in the European Green Deal to reduce greenhouse gas emissions by 55 % until 2030 compared to the reference year 1990 and to achieve climate neutrality by 2050 [1]. In this context, the industry in particular faces environmental challenges due to its high energy demand. To achieve the objective of becoming climate-neutral, increasing the energy and resource efficiency in the industry is crucial, because a large proportion of the greenhouse gases released are emitted during the provision of energy. In the automotive industry, paint shops are among the most energy-intensive processes and have great potentials for efficiency measures. These potentials can be identified with the assistance of energy or CO_2 balancing methods. This publication presents a tool to analyse the energy efficiency potentials of automotive paint shops. The approach offers the possibility to parameterize different painting processes and their sub-processes. After defining the process requirements, a thermodynamic and process engineering simulation of the individual process steps enables the identification of potentials for energy and resource savings and CO_2 reduction in existing or planned painting processes. In a validation on a real reference scenario, the simulated CO_2 emissions of a paint shop were reduced by up to 24 %.

Keywords: CO2-Accounting in Production Environments; Energy Efficiency Measures; Paint Shop Simulation

A Practical Approach to Realize a Closed Loop Energy Demand Optimization of Milling Machine Tools in Series Production (ID 17)

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Abstract: Energy efficiency is becoming increasingly important for industry. Many approaches for energy efficiency improvements lead to the purchase of new hardware, which could neglect the sustainability. Therefore, optimizing the energy demand of existing machine tools (MT) is a promising approach. Nowadays energy demand optimization of MT in series production is mainly done manually by the operators, based on implicit knowledge gained by experience. This involves manual checks to ensure that production targets like product quality or cycle time are met. With data analytics it is possible to check these production targets autonomously, which allows optimizing production systems data driven. This paper presents the approach and evaluation of a closed loop energy demand optimization of auxiliary units for milling MT during series production. The approach includes, inter alia, a concept for machine connectivity using edge devices and a concept for validating production targets.

Keywords: Energy Efficiency, Machine Tool, Optimization, Series Production, Energy Demand

Paper Session 13: Sustainable Manufacturing Processes - Manufacturing Processes
Thu, 6th Oct - 14:00 - 15:30, Room PTZ S112

3D-printed MWF nozzles for improved energy efficiency and performance during grinding (ID 107)

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Abstract: Particularly during grinding of metal workpieces, a high energy consumption is required during the main process times, so that the resulting energy costs represent a significant amount of the total operating costs of the machine tool. In this context, the supply of metal working fluids (MWF) during the grinding process is often associated with a high energy consumption, but the MWF supply strategy (MWF flow rate, MWF nozzle, control and dimensioning of the MWF supply pumps) can significantly influence the energy efficiency of such processes. In the scope of this work, additive manufacturing was used to produce fluid supply nozzles adapted to the respective grinding process. In this work, it was shown that by using a flow-optimized nozzle the required power of the MWF supply pump can be significantly reduced, allowing to make the grinding process more efficient in terms of the energy required.

Keywords: grinding; MWF supply; energy efficiency, additive manufacturing

Model-based Correlation Analysis of Machine Control Parameters and Process Vibration Amplitudes by the Example of Milling (ID 30)

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Abstract: In machining processes, system-immanent process vibrations lead not only to lower surface quality of workpieces but also to the degradation of the machine and tool wear. Effectively minimizing process vibration amplitudes without costly software or hardware add-ons is a research topic that demands further investigation. In this regard, this article focuses on the further development of a holistic milling process model as well as the experimental and simulation-based vibration analysis. The interaction between the nonlinear behaviors of the cascade controlled electric motors and the process parameters are practically evaluated. Moreover, based on the experimental and simulation results, a correlation analysis of the machine control parameters and the process vibration amplitude has been implemented.

Keywords: integrated simulation system, machining, process vibration, cascade control

A Comparative Sustainability Assessment of Cutting Fluids Usage in Band Sawing (ID 195)

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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

Design and characterization of piezoceramic thick film sensor for measuring cutting forces in turning processes (ID 206)

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Abstract: Cutting forces in turning processes usually correlate with tool conditions. For this reason, the acquisition of force signals is of key importance for monitoring purposes. Despite the robustness of current piezoelectric measuring platforms, their large weight ratio relative to standalone toolholder systems limits their effective usable bandwidth for analyzing force signals. Further limitations include high costs and lack of flexibility for general purpose turning operations. Due to this, such systems fail to find acceptance in practical applications and are mainly limited to research activities. To improve these aspects, this work investigates the use of an alternative integration concept using a piezoceramic thick film sensor for performing near-process cutting force measurements at the tool-holder. The charge output of the sensor was estimated using a coupled structural-piezoelectric simulation for its design. The modelled prototype was assembled as characterized by means of a static calibration and an impact hammer test. Following these, a first implementation of the sensor system under dry cutting conditions took place.

Keywords: piezoceramic thick film sensor, lead zirconate titanate (PZT), cutting force

The costs of more sustainable castings. Can we afford the change? (ID 86)

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Abstract: Rising costs for fossil fuels and the need to reduce emissions in the production of castings are subjecting foundries worldwide to increasing pressure to act and innovate. Due to fierce global competition in this sector and high investment costs for alternative technologies, foundries are therefore under high pressure to transform, while at the same time having limited financial resources. This article examines the economic and environmental differences between a conventional industrial foundry process chain, a process chain based on a hydrogen (H2)-fired melting furnace and an all-electric approach using conversion of H2 to electricity within a solid oxide fuel cell. To ensure an unbiased comparison of the process chains introduced, the respective mass efficiencies are first determined using an absorbing Markov chain before calculating the mass-specific costs and emissions of each approach using a literature-based process model. The comparison of the setups shows negligible differences in terms of material loss and cost in the respective best case. However, significantly higher emission minimums are found for both H2 approaches compared to the biogas-based conventional approach, especially for the use of green H2. In summary, no significant economic disadvantages of the H2-based approaches can be identified. Even considering that the economic comparison is biased in favor of biogas due to accounting measures, the environmental difference is comparatively small. The results indicate that the conversion of the foundry industry towards more sustainable H2-based foundry process chains is in principle reasonable as well as affordable and should therefore be achieved in the medium term.

Keywords: High pressure die casting, absorbing Markov chain, energy demands, greenhouse gas emissions, hydrogen in foundries

Paper Session 14: Sustainable Manufacturing Processes - Machine Tools II
Thu, 6th Oct - 14:00 - 15:30, Room PTZ 001

Development of a Pneumatic Clamping System with Position and Force Control Machining (ID 175)

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Abstract: Precision-machining plays an important role in modern, efficient and sustainable manufacturing of components in the automotive, aerospace, electronics, medical implants, biomedical, robotics and IT industries, including cutting, forming, and non-conventional processes. Monitoring and controlling the clamping forces can influence positioning accuracy, workpiece deformation, thus improving the production outcome. To improve accuracy and control workpiece deformation during machining, the clamping force must be adapted to the cutting forces, workpiece geometry and material properties. The best devices available have a repeatability of +/- 1 μm, however with limited precision and repeatability when re-clamping the workpiece. The newly developed high-precision clamping system achieves two goals: accurate positioning and force-controlled clamping. This paper presents a new adaptable clamping system for controlled high-precision positioning and re-positioning of a workpiece in the x-y plane with visual pattern recognition, adjustment, and controlled clamping forces. The clamping system is based on a pneumatic clamping chuck with controlled air pressure on a very accurate CNC machine. Accurate re-clamping is a difficult task; it may take a long time to re-position and adjust gripping force to avoid deflections and deformations of the workpiece. This paper describes FEA calculations of thin-walled workpieces and the design of associated jaws to ensure workpiece holding, limited forces and limited deformations. Once the workpiece has been removed and re-clamped with the defined forces, the vision device identifies the new workpiece position. Force and position data are collected and analyzed in a computer for calculating the repositioning movement in the x, y and theta axis. The difference between the measured position after re-clamping and the reference position is calculated using a specially developed algorithm, yielding the motion commands to the x, y and theta axis. Using the vision system made it possible to identify an accuracy of +/-1 μm and a repeatability of +/- 0.5 μm.

Keywords: High-precision clamping, Position and force control, Pneumatic chuck

Initial Period of Chip Formation: Observations towards Enhancing Machining Sustainability (ID 60)

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Abstract: In machining, high mechanical and thermal loads are exerted on a small area of the tool where it interacts with the workpiece. Despite limited interaction space, extensive use of cutting fluids (CFs) is inefficiently used to improve the machining process and increase productivity. In order to minimize CFs' negative impact on health, environment and financial burden various strategies have been developed and studied to optimize their use including minimum quantity lubrication. In this research, initial period of chip formation (IPCF), that occurs during a narrow window of space and time at the beginning of the cut, is closely investigated in an orthogonal machining setup. During IPCF, low mechanical loads were observed. The existence of IPCF is further investigated under interrupted cutting process at prescribed intervals in order to sustain its positive effects. In addition, 2D numerical chip formation friction model is proposed. The numerical model comprises a friction criterion dependent on tool temperature that is observed to be associated with a transient friction regime.

Keywords: Initial period of chip formation, Interrupted machining, MQL, Simulation, Sustainability

Influence of carbon dioxide temperature on sprayability and solubility in cryogenic minimum quantity lubrication with bio-based lubricants (ID 111)

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Abstract: Cryogenic minimum quantity lubrication (CMQL) represents a compromise satisfying both efficiency and sustainability in many manufacturing processes. In previous series of experiments a variation of the thermodynamic state of the cryogenic medium taken from riser bottles could be observed. Consequently, the aim of this study was to specifically control the thermodynamic state of the CO_2 and, associated with this, the density after removal from the riser bottles. To achieve this objective conventional cooling was implemented for the CO_2 after withdrawal from the riser bundle in order to have a constant liquid state of the CO_2 during feeding. The density of the cryogenic medium could be raised from ρ = 550 kg/m³ to over 800 kg/m at a mass flow rate of $\dot{m}CO_2$ = 5 kg/h with the applied cooling method and can also be stabilized regarding the density pulsation. Subsequently, the effects of temperature-controlled CO_2 on the sprayability and solubility in CMQL were examined and resulted in increased atomization of the oils and widening of the spray corridor with a greater main spray length and intensity. In addition stable conditions for the CMQL-supply to the manufacturing process were achieved by a lower pulsation of the CO_2-oil mixture.

Keywords: CMQL, liquid carbon dioxide, bio-based lubricants

Sustainability Enhancement of the Coal based Direct Reduction of Iron premised on a Rotary Kiln (ID 180)

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Abstract: Sustainability of steel manufacturing industries in most under developing economies around the globe has become an issue of concern bothering around both environmental and systemic sustainability. The principles of circular economy (CE) in systems thinking (ST) have been proposed in this paper as a measure towards augmenting the sustainability of coal based Direct Reduction of Iron (DRI) process. The DRI approach for steel production is preferred for economic reasons in most low-income countries, even though it is an inevitably dirty process, emitting gaseous and solid wastes in large quantities. The pollution level of the DRI process violates the United Nations sustainable development goal no. 13 which focuses on climate action. The concepts of CE in ST has been presented as a comprehensive measure that is capable of reducing and aiding with the recovery of wastes in the DRI process through effective tracing, tracking and control within an integrated network.

Keywords: Direct Reduction of Iron, Sponge Iron, Wastes, Sustainability, Circular Economy, Systems Thinking

The Influence of the Rake Angle on the Cutting of Low-Lead and Lead-Free Brass Alloys (ID 98)

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Abstract: Components manufactured from brass alloys are widely used in plumbing systems. Traditionally, lead is added to the alloy to improve the machinability. In recent years, the use of lead has been restricted due to health and environmental concerns. New lead-free and low-lead alloys were developed. These alloys usually show a higher cutting force compared to traditional lead-containing brasses. This paper investigates the influence of different rake angles and tool coating on cutting force and chip formation. The two lead-free brass alloys, CW511L and CW724R, are compared to the low-lead brass CW625N.

Keywords: Lead-Free Brass, Cutting Tool, Machinability

Paper Session 15: Sustainable Manufacturing Systems - Production Systems I
Thu, 6th Oct - 14:00 - 15:30, Virtual Session

Integrating lean management principles into human-robot collaboration in disassembly cell (ID 57)

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Abstract: Integrating Industry 4.0 technologies into the circular economy has received much attention in the literature in recent years. Considering the ladder of lansink and circular economy technical cycle, reusing and remanufacturing are preferable to recycling. Disassembly is a crucial process in remanufacturing. Collaborative robots provide semi-autonomous disassembly and could enhance product remanufacturing considering the uncertainties, cost reduction, and circularity of materials. This paper aims to discuss the application of lean practices in a disassembly cell with operators-robots collaboration. A conceptual framework based on the house of lean is proposed to highlight the research perspectives on opportunities of lean philosophy in disassembly operation enabled with industry 4.0 technology.

Keywords: Collaborative robots, lean management, disassembly, circular economy, industry 4.0

A Mathematical Model considering Multi-Skilled Operators and Industrial Robots on Reconfigurable Manufacturing Cells (ID 112)

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Abstract: A sustainable reconfigurable manufacturing system is one of the most important topics concerning sustainability. Basically, the reconfigurable manufacturing systems have two streams. One is the machine-intensive and the other is the labour-intensive. The machine-intensive means a cell formation problem (CFP) or a reconfigurable manufacturing system (RMS). On the other hand, the labour-intensive means a cellular manufacturing (CM) or a Cell Production System (CPS). Almost all manufacturing sites have these assembly lines separately, however, some advanced manufacturing sites have adopted both CM and CPS in order to absorb variability of demand and operators under the environment of limited multi-skilled operators. When the operators are replaced by industrial robots in the real world, they are called robotic cells and focused as an important component of the cyber-physical system in the large number of recent papers. Therefore, this paper tackles to indicate a multi-period mixed integer programming model to solve simultaneously 2-type cell systems considering multi-skilled operators and industrial robots on reconfigurable manufacturing cells sustainably. Firstly, the traditional model is redefined by new parameters. Secondly, the proposed model is solved by 2-phase optimization problems. Finally, the proposed model is compared with the traditional model by using numerical experiments.

Keywords: Multi-Skilled Operators, Industrial Robots, Reconfigurable Manufacturing Cells

5S Implementation to Minimize Waste in Bread Production Process (Case Study: Madani Bakery) (ID 14)

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Abstract: This paper aimed to implement the 5S concept at Madani Bakery by using PDCA (Plan, Do, Check, and Action) to reduce waste. The problems found in the bread industry have not implemented 5S so that there is waste during production activities. The method that can be used to overcome these problems is to apply 5S and PDCA so that they can make continuous improvements. The initial data used is the result of observing the initial conditions before implementing 5S and then determining Plan, Do, Check, and Action (PDCA). Based on observations at Madani bakery, two types of waste were found, namely unnecessary motion and transportation. Madani Bakery has not yet fully implemented 5S, there is still dust, items are in random condition, and there are still unused items at the work station.5S deployments are designed to improve workstations and reduce unnecessary waste movement and transportation. The limitation of this research is that the application of 5S is carried out according to the conditions of the production area at Madani Bakery. This research can be useful for Madani Bakery to create a comfortable work environment and reduce working time caused by waste during production activities. This research is expected to help Madani Bakery to implement 5S so that it becomes a work culture to reduce waste. Repairs to work stations at Madani Bakery can be used in other industries in implementing 5S and creating a work culture. Working time was cut to 784.34 minutes, and waste was cut to 11.773 minutes.

Keywords: 5S, Waste, PDCA

Environmental Assessment and Optimization when Machining with Micro-Textured Cutting Tools (ID 74)

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Abstract: The dry machining strategy has recently received high attention in the field of metal cutting as it can eliminate the environmental impacts associated with the usage of cutting fluids. However, high generated heat and severe tool wear are usually observed for the dry machining operations. One of the suggested techniques to improve the dry machining performance is to utilize the textured cutting tools, reducing the friction at the chip-tool interface. In this study, three different micro-textured tool designs were used during machining AISI 1045 at different cutting conditions. A life cycle assessment was performed including the power consumption for preparing the textured tool designs and the measured power during the machining experiments. Furthermore, some measured machining outputs (flank wear, surface roughness, and the unit volume machining time) were further included to offer a comprehensive and effective sustainability assessment for the performance of the utilized textured tools. The performance of these textured tools was also compared with the non- textured tool under the same cutting conditions. The textured tool design with narrow micro-groove width showed better sustainable performance compared to the non-textured tool and other textured tool designs.

Keywords: Textured cutting tools; Machining; Life Cycle Assessment; Sustainability; Performance Analysis; Optimization

Thu, 6th October - 16:00 - 18:30			
Paper Session 16 Sustainable Products - **Product Design and Innovation**	**Paper Session 17** Sustainable Manufacturing Systems - **Industry 4.0 & Digitalization II**	**Paper Session 18** Crosscutting Topics in Sustainable Manufacturing - **Learning and knowledge**	**Paper Session 19** Crosscutting Topics in Sustainable Manufacturing - **Strategy and Assessment**
Room PTZ S001	Room PTZ S112	Room PTZ 001	Virtual Session
Approach to Reduce the Environmental Impact of a CNC Manufactured Product in the CAD Phase (ID 80)	Development of a Potential Analysis for the Introduction of Sustainable Digitization Solutions (ID 61)	Serious games in academic education – A multi-dimensional sustainability analysis of additive versus conventional manufacturing technologies in a fictitious enterprise project (ID 69)	Holistic approach to the ecological evaluation of digitalization systems in the production environment (ID 76)
The LaST Tool – The Longevity and Sustainable Transition Tool (ID 9)	Industrial Digital Twin in Industry 4.0: Enabling service exchange between assets in manufacturing systems (ID 136)	Conversion of a Manufacturing Lab as a Learning Factory to Educate Factories of the Future Concept (ID 161)	Development of a sustainability strategy for fuel cells using life cycle analysis and expert interviews (ID 117)
A fuzzy Sustainable Quality function deployment approach to design for disassembly with industry 4.0 technologies enablers (ID 58)	Digital Twins for Sustainability in the Context of Biological Transformation (ID 47)	Evaluation of Competencies for a Sustainable Industrial Environment (ID 168)	A new Business Model for the Circular Economy of Electric Vehicles (ID 183)
Identification of Product Specifications based on KANO Model and Application to Ecodesign (ID 100)	Virtual Experiments for a Sustainable Battery Cell Production (ID 7)	Federated Learning for Privacy-Preserving Collaboration in Smart Manufacturing (ID 158)	Design model for the sustainability management of manufacturing companies (ID 79)
Concept and implementation of a student design project for the development of sustainable products (ID 106)	Conceptual Approach for a Digital Value Creation Chain Within the local Timber Construction Industry – Potentials and Requirements (ID 32)	Immersive virtual work integrated learning: a development of an interactive learning environment for rail components manufacturing. (ID 204)	Integration of digitization and sustainability objectives in a maturity model-based strategy development process (ID 99)
Classifying Multigenerational Products for the Circular Economy (ID 179)	Smart Manufacturing Systems for Small Medium Enterprises: A Conceptual Data Collection Architecture (ID 182)	A Proposed System for Greening Higher Education Institutions in Palestine (ID 3)	Implications of Strategic Orientation on Sustainable Performance and Organizational Innovation: A Case of Manufacturing SMEs in Sub-Saharan Africa (ID 43)
Design for Sustainability in Manufacturing – Taxonomy and State-of-the-art (ID 46)	Key enablers of Industry 5.0 - transition from 4.0 to the new digital and sustainable system (ID 173)	Exploring the potential of open source machine tools for sustainable industrial development in low resource contexts - A case study of migrant-run microenterprises in Oman (ID 148)	

Paper Session 16: Sustainable Products - Product Design and Innovation
Thu, 6th Oct - 16:00 - 18:30, Room PTZ S001

Approach to Reduce the Environmental Impact of a CNC Manufactured Product in the CAD Phase (ID 80)

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Abstract: CO_2 neutrality is an important goal for the upcoming years. It is necessary to ensure that greenhouse gases are emitted as few as possible, particularly for the development of new products. The most important decisions, with impact on the sustainability, are already made by the product designer during the virtual product development phase, such as raw material requirements, selected manufacturing process or thermal and surface treatments. Especially in the case of ablative processes (CNC), raw material has a major impact on the calculated carbon footprint of products. In order to minimize the emissions of greenhouse gases in the virtual product development phase already, this paper presents an approach to provide assistance for the product designer regarding the ecological impact of his decisions. For this purpose, Life Cycle Assessment (LCA) methods are directly integrated into the CAD software. During the design process, the expected CO_2 equivalents of the largest influencing factor - the raw material - can be displayed which is observed for most cases of metal material. In addition, the savings potential for reducing the blank volume or changing the raw material is shown and a suggestion is made.

Keywords: Life Cycle Assessment, Sustainable Product Development, CAD, CAM, Assistance System, Multi Scenario Analyzer

The LaST Tool – The Longevity and Sustainable Transition Tool (ID 9)

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Abstract: Due to customers' increased focus on environmental sustainability, companies have been looking to position themselves as producers of consumer goods with greater longevity. Useful tools exist within academia to assist companies in this transformation process. However, the knowledge is scattered, and the focus of tools is often on either the mapping of companies' status quo or actionable solutions that increase the longevity of their products. Creating a common understanding and coherency to make the knowledge usable in practice has proven to be difficult, as an immediate match of the most appropriate action tools to the mappings does not exist. Therefore, there is a need for a practical transition tool that, in the process of mapping, assists companies in understanding their positions and potential and proposes suitable action tools to assist in the required change process for producing consumer goods with greater longevity. This could mitigate the challenges for practitioners and bridge the different types of tools, hence enabling companies to develop products with increased longevity more easily.

Keywords: Sustainability, Tool, Product Longevity, Circular Economy

A fuzzy Sustainable Quality function deployment approach to design for disassembly with industry 4.0 technologies enablers (ID 58)

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Abstract: Integrating sustainability into product design is a proactive circular economy practice and design for disassembly is an essential eco-design practice for complex product manufacturers. Today, industry 4.0 technologies have considerable influence on product life cycle management, and a few studies address the contributions of these technologies to eco-design methods. Designing the appropriate eco-design tool is challenging considering the complexity of products, organizational instruments, the need for integrating diverse databases, customization of the tool, and incorporating the strategic goals. Hence, a systematic approach is required to address the implications of innovative technologies and integrate the different technical, economic, environmental, and social aspects into the design stage. Quality function deployment (QFD) is an effective approach to integrating customers, technical, and business requirements into new product development. Fuzzy Sustainable QFD is an extended version of this method for considering three pillars of sustainability in design and dealing with qualitative linguistic judgments. This paper proposes a Fuzzy sustainable QFD approach to design for disassembly. A numerical example illustrates the application of the proposed method.

Keywords: Fuzzy Sustainable QFD, Industry 4.0, Design for disassembly (DfD), decision support tool

Identification of Product Specifications based on KANO Model and Application to Ecodesign (ID 100)

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Abstract: It is said that KANO model is one of the key findings in analyzing and categorizing various product qualities. The model says qualities are not only one dimensional in terms of the relations between quality fulfilment and customer satisfaction. If a designer could find a delighter which can increase customer satisfaction greatly without enhancing specification too much may contribute to increase product eco-efficiency, since higher specifications usually lead to larger environmental burden. The study extracts some design specifications of smartphones and carries out an online survey to smartphone users in order to identify the relations between the specification levels and customer satisfaction levels. As the result of the survey, a true exciter could not be found in the case study products. However, regression coefficients estimated by applying conjoint analysis to the selected specifications showed there were specifications which can effectively increase customer satisfaction such as battery capacity or display size, and also there was a specification having little effect in increasing it. The survey results suggested that there are optimum values of product specifications. Identifying the optimum values and avoiding over-specification is significant in finding appropriate design solutions which may decouple the customer satisfaction and the environmental burden increase. The study concluded that the approach is helpful in enhancing product sustainability by Ecodesign.

Keywords: KANO model, Product specifications, Eco-efficiency

Concept and implementation of a student design project for the development of sustainable products (ID 106)

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Abstract: Technology is a major driver for leveraging the potential of multidimensional sustainable development, regardless of the sector examined. Therefore, engineers have an important contribution in developing innovative technical solutions to ensure more sustainable alternatives to conventional processes or products. In order to support this comprehension from an early age on, it is the task of lecturers at universities by developing students access to sustainable engineering activities with new teaching programs. Regarding conventional product development, the question arises how sustainable products can be developed, which concepts for design and which methods for validation and quantification can be used. These and further questions are the basis of the project-based learning (PBL) approach introduced in this paper as part of a new module "Development of Sustainable Products" at the Faculty of Mechanical Engineering at the Leibniz University Hannover. In this paper, the need for new courses in the ecological sustainability context and the requirements for student project work are presented. The concept of the project and the overall objective, that the students are required to assess the ecological environmental impact of electric toothbrushes over the entire product life cycle based on a life cycle assessment (LCA) is introduced. After successfully participating in this project, students are able to conduct ecological sustainability analyses and understand the complexity within the development of sustainable products.

Keywords: Project-Based Learning, Life Cycle Assessment, Sustainable Product Development

Classifying Multigenerational Products for the Circular Economy (ID 179)

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Abstract: Manufacturers are increasingly interested in the circular economy (CE) and potential of circular productions. To fully utilize CE, better guidance at the design stage is needed to establish closed-loop flows and prioritize higher value retaining end-of-use (EoU) practices such as reuse and remanufacture (i.e., parts harvesting). Intergenerational commonality (IC) is a method to increase EoU parts harvesting. However, closed-loop parts harvesting potential depends on the compatible timing between design generations' production and EoU returns curves. Therefore, in this paper, we explore an approach to make an initial assessment on where IC as a closed-loop CE strategy can produce most benefit, where such closed-loops may fall short, and what favorable design decisions can be made. The proposed indicator (based on the ratio between product's average usable lifetime and time between generation introductions, u_{avg}/t_{intro}) provides a basis for developing an objective design-support tool. Using a hypothetical example, we discuss the approach and effectiveness of this indicator. The insights gained suggest that overall production's sustainability performance show substantial improvement when $u_{avg}/t_{intro} < 1.25$, and the IC benefits are highest when $0.25 < u_{avg}/t_{intro} < 2.0$. We also highlight a few managerial insights gained from the indicator useful to strategize EoU recovery and IC.

Keywords: Circular Economy, Multi-generational products, Sustainable Manufacturing, Closed-loop production

Design for Sustainability in Manufacturing – Taxonomy and State-of-the-art (ID 46)

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Abstract: To meet sustainability goals, manufacturing companies are faced with the challenge of using renewable resources as well as innovative processes to design and manufacture sustainable products. For this purpose, the Design for Sustainability (DfS) approach has been suggested. Since there is no uniform understanding of how such a concept should work and which methods should be applied within it, the paper is intended to provide an overview of existing approaches. Therefore, a taxonomy of DfS approaches is introduced to enable a systematic and differentiated analysis. Afterwards, a literature review is conducted and a comprehensive overview of DfS concepts is provided. This allows for uncovering research needs towards an established DfS approach.

Keywords: Design for Sustainability, Design for X, Sustainable Manufacturing

Paper Session 17: Sustainable Manufacturing Systems - Industry 4.0 & Digitalization II
Thu, 6th Oct - 16:00 - 18:30, Room PTZ S112

Development of a Potential Analysis for the Introduction of Sustainable Digitization Solutions (ID 61)

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Abstract: This paper presents a methodical approach that addresses the challenges of the development process to ensure sustainable product use. Consideration of user behavior in the use phase of products is imperative for efficient support by the technical system already in the development phase. For these and other challenges, the developed approach combines methods of system engineering with the human-technology-organization approach. It helps to identify and develop optimization potential in the area of digitization solutions in the early phases of the product lifecycle. To do this, a technical system is analyzed in its current state and the requirements of the stakeholders. By defining socio-technical system elements and applying a structured approach, recommendations can be outlined holistically. As a result, the recommendations lead to an increasing level of digitization of the technical system and ensure a targeted development process. Furthermore, the methodical approach includes modeling methods to deal with the complex system behavior. The modeling language SysML as well as task-related analysis methods are used to highlight faulty states and promising aspects. In addition to the human-technology-organization triad, the basis of the developed approach is the V-model, which is applied in phase-oriented design processes or iterative design steps. This makes the usage of the approach particularly advantageous for interdisciplinary development teams.

Keywords: systems engineering, socio-technical systems, digitalization, potential analysis

Industrial Digital Twin in Industry 4.0: Enabling service exchange between assets in manufacturing systems (ID 136)

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Abstract: The idea of the Asset Administration Shell (AAS) is currently evolving into a framework for the Industrial Digital Twin in Industry 4.0 since more and more industrial use cases for its application as well as AAS sub-models with standardized semantic properties are being defined. The concept of the AAS enables data interoperability and thus provides novel opportunities for exchanging services between manufacturing assets, digital platforms, and value chain actors. Services in this sense are fabrication or assembly operations and tasks. It is demonstrated, how the data link and exchange between different AASs on the equipment level can be accomplished through an overlaying AAS on the manufacturing system level. A conceptual model for the service exchange is developed based on the state-of-the-art within the field of Industry 4.0. The model is subsequently verified and validated through a case implementation at the University of Southern Denmark's Industry 4.0 lab.

Keywords: Industry 4.0, Industrial Digital Twin and Asset Administration Shell, service exchange

Digital Twins for Sustainability in the Context of Biological Transformation (ID 47)

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Abstract: Applying biological principles that are similar to those found in nature to product engineering and manufacturing offers new approaches to product and production systems and might lead to a significant contribution towards sustainability. By transferring materials, structures, and processes of natural to digital ecosystems industrial value creation can be optimized. A promising approach to establish a networked, self-regulating digital ecosystem represents a digital twin. The potential of digital twins within the context of biological transformation has not been researched yet. This paper attempts to provide a first entry into the research topic by identifying biological principles within the concept of a digital twin and analyzing its potential for biological transformation in the industry. As a main result, the paper presents a list of relevant principles of biological transformation based on a structured taxonomy. These are specified within the concept of a digital twin.

Keywords: Biological Transformation, Digital Twin, Sustainability, Biologicalization, Digitalization

Virtual Experiments for a Sustainable Battery Cell Production (ID 7)

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Abstract: On the path towards a sustainable society, the availability of energy storage systems is an essential step – leading to increased demand for batteries. To achieve a sustainable society, it is necessary to manufacture batteries also in a sustainable way. One approach lies in virtual experiments. They aim at identifying parameters, recipes, and technologies in the digital world, before applying them to the physical production system. Thus, manufacturing is optimized in regard to sustainability indicators such as material consumption, emission, and waste – but also in regard to costs, quality, and

yield. The faster ramp-up is especially important in the production of battery cells, due to the highly complex processes and critical materials. In this paper, we introduce a concept for virtual experiments platform in battery cell production. It includes collection of data, data aggregation, a simulation environment, as well as an optimizer. Also, it is integrated into existing production and IT systems. The virtual experiments platform functions as a service of a digital twin. Validation is conducted by realizing the virtual experiments platform on the electrode production of lithium-ion batteries.

Keywords: Battery Cell Production, Sustainability, Digital Twin, Virtual Experiment, Digitalization

Conceptual Approach for a Digital Value Creation Chain Within the local Timber Construction Industry – Potentials and Requirements (ID 32)

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Abstract: This paper addresses the megatrend of urbanization as well as the associated challenges of climate change and its relation to sustainable manufacturing. On the one hand, sufficient affordable living space has to be created in the world's metropolises, on the other hand, concrete as a primary building material represents a significant negative factor in the climate balance. An offensive of the building material wood in connection with industrial prefabrication processes can make a significant contribution in this regard. The aim is not only to use the potential of wood as a renewable raw material, but also to embed wood construction in regional value chains and integrated digital production systems. This is the prerequisite for scaling wood construction on an urban level. In the context of this work, the information flows between architectural planning and serial prefabrication are first examined and aligned with a digital model. Existing digital concepts such as the "Open BIM" (Building Information Modeling) approach have been included and shaped the totality of the value-added module evolved in this work with its derived results in the form of requirements for the design of a holistic and digital value creation chain within the construction industry for wooden systems. The development of a digital value creation approach for the industrialization of residential construction with wood as the primary building material is presented in this paper. In doing so, material and information flows are analyzed, interfaces between the stakeholders have been identified, value-adding factors of wood system construction have been systematically studied for their impact and design of industrial prefabrication in order to align with a digital model.

Keywords: Manufacturing Systems; Sustainable Smart Cities; Digital Value Creation Chain; Wooden Construction

Smart Manufacturing Systems for Small Medium Enterprises: A Conceptual Data Collection Architecture (ID 182)

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Abstract: Smart manufacturing is the future of sustainable manufacturing entities with the emergence of innovative technologies readily available to foster industrial production. It becomes imperative for Small Medium-sized Enterprises (SMEs) to adopt the initiatives of the fourth industrial revolution termed Industry 4.0, to improve productivity and efficiency. SMEs are vital for the economic growth and social transformation of any nation, as such incorporating emerging technologies would generate more revenue and support sustainability. One of the major challenges facing the SMEs in a competitive and dynamic manufacturing environment is adapting the techniques and implementation of smart enabled systems. The current manufacturing data information architecture for smart manufacturing is premeditated for big organisations with funding and skills to implement such systems, however SMEs struggles to cope with such advancement. This paper aim to propose a concept based data collection architecture to aid SME using the systems of smart manufacturing for internetwork communication, prediction and analysis. This study proposes a conceptual data architecture framework, which SMEs can utilise for data collection and integrate into any type of small-scale industrial production settings to enable effective decision-making. The successful demonstration of the concept is to gear manufacturing SMEs towards smart systems with no-need for high-level implementation techniques.

Keywords: Smart Manufacturing, Data Architecture, Enterprises

Key enablers of Industry 5.0 - transition from 4.0 to the new digital and sustainable system (ID 173)

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Abstract: As Industry 4.0 has reached its first decade the new concept has appeared in the literature - Industry 5.0. With an emphasis on human role with the digital system, Industry 5.0 emphasizes the aspects of environmental awareness and sustainability in focus which serves as an upgrade to the previously presented concept. Although Industry 4.0 hasn't yet been implemented at the expected level in manufacturing companies all around the globe, this paper studies the current trends in Industry 5.0, the transition from 4.0 to 5.0 or directly to 5.0 by current evidence from the literature. Based on the given extensive literature review, this paper provides a list of key enablers of Industry 5.0, possible directions of its development, influential transitional criteria, its advantages, and barriers.

Keywords: Industry 5.0, digital transformation, sustainability, flexible manufacturing

GCSM
18th Global Conference on Sustainable Manufacturing

Paper Session 18: Crosscutting Topics in Sustainable Manufacturing - Learning and knowledge
Thu, 6th Oct - 16:00 - 18:30, Room PTZ 001

Serious games in academic education – A multi-dimensional sustainability analysis of additive versus conventional manufacturing technologies in a fictitious enterprise project (ID 69)

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Abstract: Metal additive manufacturing among other advantage offers a high degree of freedom in the design of components and shortening of conventional manufacturing process chains. Hence, there are questions of technological feasibility, efficiency and sustainability. Relevant studies, especially on the sustainability of selective laser melting, often examine only one aspect. At the same time, companies in various sectors are faced with the question of whether and if so, to what extent it is worth converting their production towards additive manufacturing. In any case, the context is filled with complex issues in several decision-making dimensions. In this paper, a special concept for academic education is introduced. It mirrors the complexity of decision-making issues, relevant problems and solutions, in a fictitious enterprise project named „AM for Future!?". The project is played as a serious game with an explicit educational purpose. It is an adaptable toolbox-like game structure on a solid methodical basis. Besides clear roles with a focus on different dimensions of sustainability, it also enables variation of products and process chains. Gameplays of different project settings, spanning over three consecutive semesters, confirm the game plan as a safe environment and suitable world of experience. For research, the output of the different game seasons can be used as a simplified parameter study. This applies to objectively quantifiable as well as different qualitative approaches. These approaches influence the answer to the question of whether and, if so, how a conventional process chain can be specifically replaced and/or supplemented with metal additive manufacturing.

Keywords: Serious Game, Sustainability, Additive Manufacturing

Conversion of a Manufacturing Lab as a Learning Factory to Educate Factories of the Future Concept (ID 161)

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Abstract: The demand for enhancing the flexibility and efficiency of the manufacturing industry has rapidly increased over the years due to mass customization to cater to the needs of society. The conventional manufacturing industry could not survive these rapid changes. Though, the manufacturing sector is the forerunner to embrace technological paradigm shift, which paves the way for Industry 4.0 or the 4th industrial revolution. With Industry 4.0, now many world leaders are moving towards a new concept called "Factories of the Future" (FoF), which predominantly engages with the cyber-physical world to digitalize manufacturing while maintaining a strong link between hardware and the cyber-physical world. To perform any manufacturing, engineering teaching/learning programs should introduce these concepts with some practical exposure, which will enable students to contribute to the manufacturing industry all around the world. Therefore, this study focuses on

converting an old manufacturing lab into a learning factory to promote FoF concept. This is achieved by enabling existing manufacturing machines to be digitally connected via Industry 4.0 while creating connections with the other machines to create flexible manufacturing systems (FMS). Competencies in integrated scheduling of machine centers and autonomous material handling systems were also explored. Furthermore, the study suggested that the conversion of the manufacturing lab needs to be done in many different integration platforms.

Keywords: Learning Factory, Factories of the Future (FoF), Industry 4.0, Internet of Things (IOT), Flexible Manufacturing System, Integrated Scheduling

Evaluation of Competencies for a Sustainable Industrial Environment (ID 168)

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Abstract: The organisation of worker activities in manufacturing shops have been differently conceived depending on political, societal, environmental and economic circumstances affecting industrial development. From Taylorism and Fordism, through Lean Manufacturing to the innovative Cell Production system, the level and quality of abilities and competencies of workers have increasingly become the kernel of factory management models. Mass customization and product uniqueness have today substituted mass production. The importance of Sustainability in manufacturing has increasingly become a crucial factor for product success. The design and manufacture of industrial products are nowadays conceived in circular loops within the 6R framework. The digitalisation of the information has allowed significant advancements in vertical and horizontal integration within an enterprise. Qualified and skilled operators have accompanied and led these evolutions, and their abilities and creativity have got a growing relevance, despite the continuous increase in automation. The purpose of this work is to investigate the contribution of craftsmanship abilities in the industrial environment. For this purpose the Craftsmanship Index has been proposed to assign a quantitative value to the craftsmanship skills contributing to the manufacturing activities. This index is useful to analyse worker abilities and the way they are learned and developed, being part of effective management and decision-making tools. In previous studies has been implemented in Italy. A case study carried on in the Japanese manufacturing environment is presented here. A customised questionnaire to be administered to workers is used to calculate the Craftsmanship Index. The calculation of the Craftsmanship Index allowed us to give a quantitative relevance to the level of abilities of operators depending on the analysed department. Some cultural differences have also emerged thanks to the comparison between the Japanese and the Italian culture, thus leading to an expansion of this approach.

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

Federated Learning for Privacy-Preserving Collaboration in Smart Manufacturing (ID 158)

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Abstract: Manufacturers today are increasingly connected as part of a smart and connected community. This transformation offers great potential to deepen their collaborations through resource and knowledge sharing. While the benefits of artificial intelligence (AI) have been increasingly demonstrated for data-driven modeling, data privacy has remained a major concern. Consequently, information embedded in data collected by individual manufacturers is typically siloed within the bounds of the data owners and thus under-utilized. This paper describes an approach to tackling this challenge by federated learning, where each data owner contributes to the creation of a global data model by computing a local update of relevant model parameters based on its own data. The local updates are then aggregated by a central server to train a global model. Since only the model parameters instead of the data are shared across the various data owners, data-privacy is preserved. Evaluation using sensor data for machine condition monitoring has shown that the global model produced by federated learning is more accurate and robust than the local models established by each of the single data owners. The result demonstrates the benefit of secure information sharing for individual manufacturers, especially Small and Mid-Sized Manufacturers (SMMs), for improved sustainable operation.

Keywords: Smart manufacturing, Federated learning, Data privacy

Immersive virtual work integrated learning: a development of an interactive learning environment for rail components manufacturing. (ID 204)

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Abstract: Undergraduate students pursuing their studies in the engineering discipline in higher education institutions (HEI) are expected to complete their work integrated learning (WIL) component as part of their curriculum. This is a compulsory module traditionally performed in the workplace environment over a specified time. However, with the scarcity of placement-based WIL, as well as the Covid-19 pandemic, there has been a reduction in the intake of students to accomplish their studies. This paper presents, a human centered design (HCD) model for developing an immersive virtual reality (IVR) rendered with an HTC Vive Pro head mounted display (HMDs) platform capable of training industrial engineering undergraduate students on the manufacturing procedure of rail components using a reconfigurable guillotine shear and bending press machine (RGS&BPM) as part of the set of immersive virtual work integrated learning (IVWIL) activities. The study explores current literature and the HCD approach to designing and developing the immersive interactive training platform. It highlights the important aspects of the development of the immersive virtual environment and recommends future work.

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

A Proposed System for Greening Higher Education Institutions in Palestine (ID 3)

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Abstract: This article tackles the problem of greening university campuses of higher education institutions in Palestine. The paper concentrates on finding the adequate greening categories and key performance indicators to be used to assess the sustainability and green of higher education Institutions HEI. Each indicator has been weighted based on the opinion survey filled by academic experts from the different Palestinian universities. The weights of these indicators have been normalized to come up with a category score and a then a total score of the greening of the HEI. Eventually, a Go-Green integrated model is developed to form an initiative for any higher education institution wishes to enter into this sustainability race. Many steps and activities are suggested to turn any university to a green one. Through implying the Elasticity and Plasticity approach, it is possible to relate the level of green actions to social behavior. The impact of these sustainability aspects is reflected on higher education by implementation on university campus greening.

Keywords: Sustainability; Green campus; Elasticity-Plasticity; Go-Green model; Social behavior; Key performance indicators

Exploring the potential of open source machine tools for sustainable industrial development in low resource contexts - A case study of migrant-run microenterprises in Oman (ID 148)

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Abstract: In low resource contexts, access to technologies is limited. Most firms in developing countries are still using analog technologies and have not attained the industrial maturity required to harness the benefits of industry 4.0, which include increased productivity and a reduced environmental impact of the manufacturing sector. This further exacerbates the unequal wealth distribution pervasive in today's globalized world. With the democratization of the internet and increasing accessibility to microcontrollers and automation technology, the last decade has seen the rise of open source machine tools (OSMT) such as CNC mills and 3D printers. By facilitating sustainable and inclusive production capacity building, OSMT are a key technology driver that can enable developing countries to leapfrog their industries. However, their potential for cost effective and low-threshold production capacity building in developing countries has been hitherto underexplored. This paper reports the findings of a pilot study in Oman with ten migrant-run microenterprises in the carpentry and steel fabrication industries. Semi-structured interviews and field observations were carried out to gain an understanding of the technology needs and readiness levels of the target group. The study identifies and discusses the challenges that could hinder the implementation of OSMT in a resource constrained context, which include insufficient technological and digital literacy, a lack of formal education, and risk adversity. Based on this, the paper proposes solutions to foster OSMT adoption.

Keywords: Microenterprises; Democratizing Manufacturing; Open Source Machine Tools; Resource Constrained Contexts; Sustainability

Paper Session 19: Crosscutting Topics in Sustainable Manufacturing - Strategy and Assessment
Thu, 6th Oct - 16:00 - 18:30, Virtual Session

Holistic approach to the ecological evaluation of digitalization systems in the production environment (ID 76)

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Abstract: Digitalization is considered as a driver of resource efficiency. But next to the possible savings that the different digitalization technologies enable, there is an ecological effort, too. Most of the existing approaches in this topic only consider the possible savings. The presented methodology forms an approach for a holistic environmental assessment along the whole life cycle of digitalization technology and validates it on a demonstrator. The aim is to take an end-to-end view of the use of digitalization technologies. As part of the approach, the global warming potential is evaluated. The benefit here is a production environment in which the digitalization technology used generates savings. For the evaluation, the digitalization system (hardware) is considered from the manufacturing process of the different components through transport and operation to recycling (cradle to grave). As practical case study, effort and benefit are finally analyzed for different resource efficiency scenarios. As a result, a methodical approach based on key figures for the holistic evaluation of digitalization technologies is presented and discussed.

Keywords: digitalization of production systems, holistic ecological evaluation, woodworking

Development of a sustainability strategy for fuel cells using life cycle analysis and expert interviews (ID 117)

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Abstract: Fuel Cells (FC) are one of the most promising technologies for achieving the European climate targets, especially for future mobility. As part of the German government's national hydrogen strategy, measures for the further development and implementation of FC technology as a drive technology in automobiles as well as the production and use of hydrogen were adopted in June 2020. For Germany to be a pioneer in the field of FC technology, the investments must be used sustainably. The objective of this paper is to introduce a sustainability strategy for FCs along the life cycle via production, energy sources, infrastructure, use as well as end-of-life. To present an overview of this existing value chain, life cycle analyses are compared and hypotheses for increasing sustainability are formulated. These serve as the basis for the development of interview forms for discussions with FC experts from research, industry, and politics. Based on the current state of the art and its optimization potential as well as the insider knowledge of the experts, a sustainability strategy for FC-powered automobiles is presented.

Keywords: Fuel Cells, life cycle analysis, sustainability

A new Business Model for the Circular Economy of Electric Vehicles (ID 183)

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Abstract: The market for electrical vehicles (EVs) is expected to show a constant growth in the next years. However, Europe is not prepared to manage such a massive flow of electric vehicles at the end-of-life (EoL). Consolidated value chains including recyclers, remanufacturers, and dismantlers able to treat key parts of EVs efficiently and safely at the EoL (such as batteries) do not exist at the needed industrial scale due to their novelty and complexity which requires innovative technologies and methods. Furthermore, the huge uncertainty on the volume of parts, their EoL conditions, materials cost fluctuations, and market acceptability discourage companies from starting new recycling/remanufacturing businesses. This carries the risk of delaying the consolidation of European value chains specialized in the EoL management of EVs. In order to address these challenges, the present research, which was carried out in the frame of the H2020 "CarE-Service" European funded project, proposes a new circular business model for the EoL management of EVs.

Keywords Circular Economy, Automotive Supply Chain, End-of-Life vehicles management

Design model for the sustainability management of manufacturing companies (ID 79)

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Abstract: This paper presents a design model that supports the systematic steering and operationalization of sustainability in manufacturing industry at all corporate levels. Studies show (e.g. Ramboll Group, Smurfit Kappa) that companies are aware of both the need for and the opportunities of corporate sustainability. Corporate sustainability means improving environmental and social effects as well as conditions, while operating profitably in the long term. However, companies face the challenge of resolving the complexity of corporate sustainability. Due to this challenge, the sustainability management model presented in this paper provides a holistic framework that addresses the relevant elements, fields of action and interrelationships of sustainability management in manufacturing companies. A top-down approach enables the management of sustainability at several corporate levels. In addition, various design elements enable the integration of sub-models through which a further concretization and operationalization of corporate sustainability can be realized.

Keywords: Sustainability Management, Sustainable Production

Integration of digitization and sustainability objectives in a maturity model-based strategy development process (ID 99)

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Abstract: Political, technological and economic changes force manufacturing companies to shift their strategic alignment towards green and digitized technologies. The parallel advances in those technologies raise questions regarding economic, environmental and social sustainability issues that are challenging to integrate into corporate strategy. Recently, sustainable energy supply has gained additional attention as a critical resource for production. Digital transformation is a diverse intracompany process and requires adequate strategies. Maturity models are a well-known and established approach to define strategic improvement measures. Various versions of separate maturity models to either examine the current state of digitization or sustainability have been developed and there are few models to support both dimensions adequately. Therefore, the authors propose a strategy development process, which utilizes a combined maturity model for both domains in one framework. A review on sustainability-related maturity models as well as the connection to digitization aspects is conducted. Based on this, an existing model is extended. The model is tested in a case study to compare the impact of the models' adaptions.

Keywords: Digitization, Sustainability, Maturity Model

Implications of Strategic Orientation on Sustainable Performance and Organizational Innovation: A Case of Manufacturing SMEs in Sub-Saharan Africa (ID 43)

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Abstract: The ability of manufacturing small and medium-sized enterprises (SMEs) to adopt sustainability is predicated on several criteria, including purchasing and developing specialized resources. SMEs in emerging economies have great potential, and in terms of intensifying business performance, it is important to focus on strategies orientation. The influence of four strategic orientations on firm performance is examined in this study. The role of learning, entrepreneurial, technological, and environmental orientations within proactive strategic orientations in the manufacturing sector have been investigated. This study uses a survey questionnaire to collect data from four hundred and sixty-five sub-Saharan African manufacturing SMEs. The proactive strategic orientations were advantageous for organizational innovation (OI) and sustainable performance (SP); OI improves SP, and SP catalyzes OI, based on the Pearson correlation coefficient. This research provides information that may be utilized to advance conceptual and practical debates on manufacturing SMEs to be innovative and improve their sustainability performance to contribute to society, the environment, and the economy.

Keywords: Manufacturing SMEs, Strategic Orientations, Proactiveness

Fri, 7th October - 11:00 - 12:30			
Paper Session 20 Sustainable Manufacturing Systems - **Life Cycle and Decision Making II**	**Paper Session 21** Crosscutting Topics in sustainable Manufacturing - **Sustainability at Regional Level**	**Paper Session 22** Sustainable Manufacturing Systems - **Advanced Digitalization**	
Room PTZ S001	Room PTZ S112	Room PTZ 001	
Dynamic LCA and LCC with ECOFACT (ID 152)	Converted and shared Light Electric Vehicles in Ghana: A technical and economic analysis based on converted ICE motorbikes and e-mopeds (ID 64)	A Short Overview Of Neural Networks For Energy Optimization Of Production Processes In Small And Medium Sized Enterprises (ID 192)	
Sustainability assessment of aerospace manufacturing: an LCA-based framework (ID 91)	New insights into the polymer coating of mild steel using Activated Orange juice functionalized Rice husk nanoparticles (ID 150)	Establishment of an appropriate data analytic platform for developing a Wisdom Manufacturing System using decision techniques (ID 108)	
Concept for the Evaluation and Categorization of Sustainability Assessment Methods and Tools (ID 40)	Supply Chain Reconfiguration as an Option to Mitigate Post Harvest Losses and GHGs: Simulating a Case Study from Banana Supply Chain in Sri Lanka (ID 171)	Implementation Framework for Blockchain-Based Traceability to Tackle Drug-Counterfeiting: Embracing Sustainable Pharma Logistics Networks (ID 67)	
Techno-Economic Assessment of Biogas to Liquid Fuel Conversion via Fischer-Tropsch Synthesis: A Case Study of Biogas Generated From Municipal Sewage (ID 119)	Design of a sustainable rescue and first aid drone-based system for passenger car occupants (ID 21)	A Hybrid Structural Interaction Matrix approach to prioritise process wastes generated in a manufacturing organisation (ID 105)	
Model-based method for low-effort part-specific CO2-accounting during the production on machine tools using PLC data (ID 82)		Modelling and simulation of pump impeller produced using Fused Deposition Modelling (ID 104)	

Paper Session 20: Sustainable Manufacturing Systems - Life Cycle and Decision Making II
Fri, 7th Oct - 11:00 - 12:30, Room PTZ S001

Dynamic LCA and LCC with ECOFACT (ID 152)

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Abstract: This paper introduces the work on dynamic life cycle assessment (LCA) and life cycle costing (LCC) carried out within the EU Horizon 2020 project ECOFACT. The goal of the ECOFACT project is to develop a digital platform for manufacturing companies to optimize their production systems for energy, costs, resources and life cycle impacts. The platform will include a manufacturing decision-support-system based on dynamic LCA and LCC and it will be demonstrated in four factories that are members of the project consortium. Dynamic and automated LCA and LCC provides opportunities for new insights compared to conventional, static assessments. For example, temporal variations in the environmental impact can be made available on an hourly, daily, monthly and yearly basis. Moreover, once set up, LCA and LCC results can automatically be updated with the latest data, reducing efforts and costs related to data collection and reporting. In this paper, we briefly explain the ECOFACT approach to dynamic LCA and LCC and discuss preliminary learnings as well as future opportunities.

Keywords: Life Cycle Assessment, Smart Manufacturing, Life Cycle Costing, Industry 4.0, Sustainability

Sustainability assessment of aerospace manufacturing: an LCA-based framework (ID 91)

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Abstract: In this paper, a life cycle assessment (LCA)-based sustainability assessment framework is developed to estimate the environmental impact of production processes. The framework provides a methodical, context-independent, approach to carry out LCA studies. The framework sets guiding principles for products and key performance indicators (KPIs) selection and the associated data requirements in a reconfigurable manner that can be applied to any industrial setting. In order to validate and demonstrate the applicability of the framework, a cradle-to-gate case study pertaining to the manufacturing of a real aerospace metallic structural component is carried out. Results revealed that the complexity of aerospace components makes it difficult to improve the environmental impact from manufacturing operations as most of the impact comes from upstream activities that aerospace manufacturers, typically, have no control over, or access to.

Keywords: Sustainability assessment, Life cycle assessment, Aerospace manufacturing

Concept for the Evaluation and Categorization of Sustainability Assessment Methods and Tools (ID 40)

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Abstract: Sustainable product development is one key to avoid overshooting the global production resources and to keep the human impact on the climate under control. Life cycle assessment provides methods and tools to monitor and quantify processes. In reality however, this is a complex procedure with a lack of transparency and standardization. Especially small and medium enterprises lack resources and know-how to successfully perform life cycle assessments. Therefore, the need for action is to make methods and tools usable and accessible in practice. This paper presents a concept for the evaluation and categorization of sustainability assessment methods and tools by developing criteria based on a system context and stakeholder analysis. Proven assessment methods from literature and market research are the basis for the development of this concept. The final evaluation of exemplary solutions leads to research gaps which can be addressed in the future development of assessment methods.

Keywords: Life Cycle Assessment, Sustainable Product Development, Sustainability Assessment Methods and Tools, Life Cycle Engineering

Techno-Economic Assessment of Biogas to Liquid Fuel Conversion via Fischer-Tropsch Synthesis: A Case Study of Biogas Generated From Municipal Sewage (ID 119)

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Abstract: This research looks at how biogas (a renewable energy resource) can be harnessed using municipal sewage waste, and the potential of biogas use to generate liquid fuels (diesel and petrol) using Fischer Tropsch synthesis. It also looks at the economic nature of carrying out the venture to determine the viability of developing such an initiative in Zimbabwe. The production of drop-in biofuel from biogas via Fischer Tropsch synthesis was successfully simulated using Aspen Plus simulation tool to conduct the techno-economic assessment. For the base case plant capacity of 2000 Nm3/h, the minimum selling price of Fischer Tropsch diesel and petrol fuel was determined to be slightly under \$4/gal with an annual plant capacity of 200 million litres/year. This plant was designed to produce 1700 barrels/day of petrol fuel that can be refinery for further upgraded to commercial grade gasoline for export. The plant was also designed to produce 2000 barrels/day of diesel fuel for direct use as liquid transportation fuel. The total biogas input requirement is 700 tonnes/hour of biogas (2000m3/hour) [1m3=0.353 tonnes]. Total sulphur production is 30 tonnes per day, and total carbon dioxide capture is 1500 tonnes per day. The total plant cost was estimated to be \$200 million USD. The financial analysis for a base case shows positive financial performance with nearly 20% return on investment. A payback period of 5 years was projected.

Keywords: Fischer-Tropsch, Biogas, Fuel Conversion

Model-based method for low-effort part-specific CO2-accounting during the production on machine tools using PLC data (ID 82)

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Abstract: Against the backdrop of advancing climate change, the pressure on industry as the second largest producer of greenhouse gas emissions worldwide is increasing. Climate neutrality and the effects on the climate of products or services are gaining more and more political and social attention. Thus, this paper is dedicated to the investigation of the holistic influence of machined components on greenhouse gas emissions. Optimisations can only be achieved through a profound understanding of the important factors in relation to climate neutrality of industrial production. To this end, a method is developed that allows the low-effort quantification of part-specific greenhouse gases emitted during the production on a CNC machine tool. Validating experiments are conducted in a real industrial environment. Finally, potential for improvement is outlined.

Keywords: CO2 emission, Sustainable production, Manufacturing

Paper Session 21: Crosscutting Topics in sustainable Manufacturing - Sustainability at Regional Level
Fri, 7th Oct - 11:00 - 12:30, Room PTZ S112

Converted and shared Light Electric Vehicles in Ghana: A technical and economic analysis based on converted ICE motorbikes and e-mopeds (ID 64)

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Abstract: This paper sets out to examine the economic and technical viability of LEVs in Ghana as a business model. It further examines the profitability of converted motorbikes which are adapted from ICE motorbikes. The business model is built on technical requirements of the ICE conversion in Ghana. The authors used a case study approach to analyze an exemplary business model based on 40 e-mopeds and 20 stand-alone solar charging stations deployed on the campus of KNUST until December 2021. A further analysis was also done on the process of converting an ICE motorbike to create a minimum viable product which runs on electricity. The business model examines the profitability of such converted motorbikes taking into account production and assembly costs whiles also considering fixed costs. The results of the analysis prove that a single e-moped deployed in the model was profitable after 6.3 years and a converted motorbike was profitable compared to a conventional motorbike between 22500Km to 32500Km of use depending on the purchase scenario. The discussion and results provide a good basis for further research and give support to sustainable business models and manufacturing of LEVs.

Keywords: Electromobility; Sharing Systems; Sustainable Business Models

New insights into the polymer coating of mild steel using Activated Orange juice functionalized Rice husk nanoparticles (ID 150)

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Abstract: Novel insights in the development of polymer coating of mild steel using functionalization of rice husk ash nanoparticles by activated orange juice were investigated. For the potentiostat/galvanostat corrosion performance of the coated materials, 5 wt% potassium sulfate (K_2SO_4(aq), 5 wt% sodium chloride (NaCl(aq), and 1 M sulfuric acid (H_2SO_4(aq)) were used. 78.81, 71.86, and 55.11% corrosion resistance of the samples of K_2SO_4, H_2SO_4, and NaCl. It was concluded that orange juice was able to enhance the dispersion of RHnp in the epoxy coating. The presence of citrate ions in the orange juice acts as a stabilizer and reducing agent, which was attributed to the fine grain size and good corrosion resistance of the composite coating. The work has established that rice husk ash nanoparticles by activated orange juice can be used in the development of composites coating mild steel.

Keywords: Rice husk, Orange juice, microstructure, Corrosion, and Nano-particle

Supply Chain Reconfiguration as an Option to Mitigate Post Harvest Losses and GHGs: Simulating a Case Study from Banana Supply Chain in Sri Lanka (ID 171)

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Abstract: Zero hunger is one of the top three goals of Sustainable Development Goals which is achievable by reducing the postharvest losses of the food supply chain and improving food security. In developing countries approximately 40% of fruit harvest goes to waste due to not having proper mechanisms, coordination and best practices and poor post-harvest management. A pilot study has found post-harvest losses of fresh fruits and vegetables occur in 2.29%, 1.57%, 6.22% and 7.89% at farmer, collection center, wholesaler and retailer respectively, emphasizing the need of a reconfiguration. Following good practices in handling, introducing suitable bulk packing methods, vehicle upgrades and development of different supply chain configurations are some approaches in mitigating post-harvest losses. Therefore, it is timely to change the product flow of supply chain by reconfiguration. The existing configuration of fruit and vegetable supply chain is simulated as an agent based simulation model taking banana supply chain as a case study. Short supply chain branches were introduced as suggestions to avoid the congestion and banana getting exposed to mechanical damages. The reconfigured supply chain emitted 10% less GHG than the existing banana supply chain while achieving the efficiency in distribution flow.

Keywords: Reducing PHL; Supply chain reconfiguration; Agent based simulation

Design of a sustainable rescue and first aid drone-based system for passenger car occupants (ID 21)

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Abstract: Medical emergencies transpire in passenger cars where most victims fail to access immediate medical assistance bringing about worsening of their health or death. Incorporation of rescue and first aid drone-based systems in Emergency Medical Services has been proposed. The objectives being improving response time of Emergency Medical Services, assessing the victim's health, assisting in administration of first aid, real time live feed of victim's vitals to the responders and mainly to outline how sustainability in healthcare can be achieved through adaptation of the proposed system. The key features of the first aid drone-based system include: a compact, architecture, aerodynamically optimized architecture and high strength to weight ratio. Solid Works has been used for modelling and simulation of the proposed system. Results showed that the maximum stress (295MPa) experienced in the link is less than the yield strength of carbon fiber (1000MPa), therefore, the design is safe. Findings also showed that, the proposed system can help to further bridge the gap between technology and healthcare, hence making the current healthcare system more relevant in future. Recommendations have been made on improving the software design of the system. Further studies on the design of quadcopters with high range, payload, endurance and speed has been proposed. Overall, the research focused on how robotics, Artificial Intelligence, and Internet of Things (Industry 4.0) can been used to improve Emergency Medical Services response to health emergencies.

Keywords: Artificial Intelligence, Emergency Medical Services, First Aid, Health Emergencies, Industry4.0, Internet of Things, Passenger Car, Robotics, Sustainability

Paper Session 22: Sustainable Manufacturing Systems - Advanced Digitalization
Fri, 7th Oct - 11:00 - 12:30, Room PTZ 001

A Short Overview Of Neural Networks For Energy Optimization Of Production Processes In Small And Medium Sized Enterprises (ID 192)

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Abstract: This article describes the conception and development of an artificial neural network for the optimization of production processes regarding the reduction of energy under the aspect of quality assurance for manufacturing SMEs. It describes the development and implementation of the model for the analysis and adaptation of parameter settings to machines in the production process, which determines the ideal configuration to reduce energy consumption and improve quality. For this model, 4 machines with 30 parameters with a total of 777,458 data sets are considered. For each of the machines, the ANN returns the parameters with the greatest influence on potential savings with their optimal settings. The calculations show that the heating and injection pressure parameters are the most promising. In the test of the model of a plastic-producing SME, it was proven that a total annual energy saving of 50,000 kWh can be achieved.

Keywords: Artificial Neural Networks; Environmental Informatics; Resource Efficiency

Establishment of an appropriate data analytic platform for developing a Wisdom Manufacturing System using decision techniques (ID 108)

Emanuel Fernando Zeferino[1], Khumbulani Mpofu[1], Olasumbo Makinde[1] and Boitumelo Ramatsetse[1]

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Abstract: In today's global business context, data has played a critical role in ensuring accurate and appropriate decision making in manufacturing organisations. Despite the huge pool of data generated by the consumers, maintenance shops, manufacturing job shop, and scientific society on various products, which could be deployed by manufacturers in eliciting vital information towards achieving sustainable product design and development, only few manufacturers are making use of this data to generate wisdom required for sustainable manufacturing. This act is caused by lack of appropriate systems capable of integrating the available data and make wise inferences that will result in a competitive advantage of a specific organisation over its competitors. Hence, this study establish a suitable data analytic platform that could be used to sort, classify and integrate data required to generate wisdom vital for sustainable manufacturing. In order to achieve this, Analytical Hierarchy Process (AHP) was deployed to appraise various alternative data analytical platforms using various criteria. The result of this decision analysis and selection exercise, revealed that KNIME data analytic platform, with a cumulative assessment score of 80.80 is the appropriate data analytic platform that manufacturers should use to generate a knowledge advisor vital for sustainable manufacturing and product development.

Keywords: Wisdom Manufacturing, Data Analytics, Analytical Hierarchy Process, Decision Analysis

Implementation Framework for Blockchain-Based Traceability to Tackle Drug-Counterfeiting: Embracing Sustainable Pharma Logistics Networks (ID 67)

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Abstract: Fighting counterfeit drugs in pharma logistics networks, is one of the most important challenges in the industry. In order to contribute to the UN Sustainable Development Goal of "global health and well-being" the integration of counterfeit substances and drugs has to be stopped but is still causing significant human and economic damage. Although the problem is known for decades no approach is known that eradicates the problem. Blockchain technology is promoted as a potential solution to counterfeit drugs since it combines the properties of tamper-proof data storage and secure information transfer but its' application in the pharma industry is still lacking behind the theoretical potential. This study seeks to assess the applicability of blockchain technology to tackle drug counterfeiting in pharma networks and to develop an implementation framework that outlines industry-specific implementation barriers and mitigation measures as well as their interdependencies. Building on nine interviews with industry experts, Grounded Theory was applied. Accordingly, the interview results were condensed into a theory by applying a three-stage coding process. Building on this analysis, an implementation framework for blockchain technology to tackle drug counterfeiting in the pharma industry is developed. The framework explains the enablers, barriers, and implementation strategies as well as the relation between them. It is shown that blockchain implementation is not hindered by a lack of technological maturity, but mostly by opposing incentive mechanisms of stakeholders involved.

Keywords: Pharmaceutical supply chain, distributed ledger networks, blockchain, drug counterfeit, transparency

A Hybrid Structural Interaction Matrix approach to prioritise process wastes generated in a manufacturing organisation (ID 105)

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Abstract: The productivity of a manufacturing organisation is limited by myriads of process wastes generated in this organisation. In light of this, the aim of this study is to prioritise various process wastes generated in a manufacturing organisation. In order to achieve this, on the one hand, a Hybrid Structural Interaction Matrix (HSIM), which is premised on the theory of subordination via systems thinking was deployed to carry out the process wastes pairwise ranking and weighting analysis. On the other hand, the Pareto Chart, was thereafter deployed to ascertain the vital few process wastes contributing to productivity loss experienced in a manufacturing organisation. A case study of the process wastes generated in an Electronic-Product Manufacturing organisation was used to validate the process wastes prioritisation model developed in this study. The result of the HSIM prioritisation analysis revealed that the intensity rating scores of the process wastes; overproduction, excess inventory, defect, motion, transport, waiting and over-processing limiting the productivity of an organisation are 7.53, 4.59, 6.06, 1.65, 3.12, 0.18 and 9 respectively. The result of the validation exercise revealed that transport, excess inventory and defects are the core process wastes that limit the productivity of an Electronic-Product Manufacturing organisation considered in this study. With this approach, operations managers of a manufacturing organisation would obviously reduce errors in the rating of process wastes, which is vital towards achieving continuous productivity improvement and sustainable manufacturing.

Keywords: Process Wastes, Hybrid Structural Interaction Matrix, Pareto Chart, Productivity

Modelling and simulation of pump impeller produced using Fused Deposition Modelling (ID 104)

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Abstract: Additive Manufacturing (AM) is a key Fourth Industrial Revolution (4IR) technology in which parts are manufactured directly from 3-dimensional models through selective deposition of materials. As a digital technology, AM can be used to produce complex parts that are difficult to make using traditional methods without the need for tooling. Hence, the aim of this study is to investigate the performance of Fused Deposition Modelling (FDM) in the manufacture of pump impellers. This involves performing simulation to test the performance of pump impeller under real-life working conditions at different operating speeds and pressures. The model of the impeller as casted in the FDM process was developed in the complete Abaqus modelling environment. The model part was created as single solid homogenous part with no nodal separations or assembly ties or constraints between the base of the impeller and its blades, in relation to its as-cast manufacturing state. The results obtained showed that extreme operating speeds of up to 1000 rad/s or pressures of 0.22 MPa are not suitable conditions under which the impeller will operate without compromising its efficiency and structural integrity. The study is useful in providing guidance on the application of FDM to produce functional parts. Through the study, the capability of AM as a suitable approach for enabling local sustainable production of spare parts is demonstrated.

Keywords: 4IR, AM, FDM, Pump impeller, Simulation

Fri, 7th October - 14:00 - 15:30			
Paper Session I Sustainability oriented student projects - **Team Presentations and Discussions**			
Room PTZ S112			
Leveraging Insights from Unique Artifacts for Creating Sustainable Products (ID 169)			
Literature review of Biological Transformation in Holistic Production Systems (ID X)			
Evaluating the Sustainability of Paper and Plastic Substitute Material LimeX (ID 209)			
Requirements for the development of a performance management system with consideration of unforeseeable business process variants (ID X)			
Circular business models and digital technologies – leveraging the potentials of a Circular Economy (ID X)			

Paper Session I: Sustainability oriented student projects - Team Presentations and Discussions
Fri, 7th Oct - 14:00 - 15:30, Room PTZ S112

Leveraging Insights from Unique Artifacts for Creating Sustainable Products (ID 169)

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Abstract: Sustainable manufacturing pursues the achievement of economic, environmental, and societal benefits by promoting the long-term use of materials, products, and components within a circular economy. The analysis of one-of-a-kind classical products reveal some designs that exhibit a creative combination of parts from a variety of industrial sectors. For example, Italian designers behind some innovative artifacts have managed to integrate components from different sources into attractive and emotional-oriented objects that are revered to this day. The present work aims to combine 6R-based sustainable manufacturing with insights gained from some classical products of Italian design characterized by simplicity and decontextualization of common objects. This manuscript presents the design process for leveraging concepts embodied in some unique artifacts from the Italian design movement to inspire the realization of sustainable products. A commercial household item was redesigned to demonstrate the application of the approach by utilizing end-of-life items collected from municipal solid waste. The potential benefits of the triple bottom line approach associated with leveraging concepts, such as those from Italian design, to develop more sustainable products is also discussed.

Keywords: Sustainable manufacturing; 6Rs; Italian design; Sustainable design

Literature review of Biological Transformation in Holistic Production Systems (ID X)

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Abstract: In today's manufacturing world, there are large, interconnected production networks. Production is constantly influenced by trends such as the Toyota production concept or Holistic Production System. Numerous companies have already introduced a Holistic Production System. Though, to achieve the greatest success with it, the Holistic Production System must be implemented across the entire production network. This means that more and more companies are setting a condition for their suppliers: They must also implement a Holistic Production System. However, not only the introduction but also the maintenance of a Holistic Production System is associated with a high level of effort. To reduce the effort required for a Holistic Production System, Biological Transformation offers a promising approach. Especially since principles from nature are resource-saving. This paper presents a systematic literature review. This review examines the extent to which biological principles are already being used in Holistic Production Systems.

Keywords: Holistic Production System, Biological Transformation, Literature review

Evaluating the Sustainability of Paper and Plastic Substitute Material LimeX (ID 209)

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Abstract: With the increasing decline in the environment and natural resources it is important to find new ways in which manufacturing can increase the sustainability of the world. This study seeks to compare LimeX, a state-of-the-art paper and plastic alternative primarily made of limestone, with conventional paper and plastic materials. For a better understanding of LimeX as a material, a brief investigation of the mechanical and chemical properties will be performed through experimentation and analysis. In addition, this paper aims to evaluate the sustainability of LimeX through the analysis of metrics relating to the triple bottom line (environmental impacts, economic impacts and societal impacts) to evaluate and compare the sustainability performance of LimeX products with conventional paper and plastic products. The previously developed Product Sustainability Index (ProdSI) will be adapted and used in this study to conduct the sustainability evaluation. Major findings will include results from an experimental analysis of LimeX via SEM and EDS, and LimeX material property measurements via tensile testing and density measurements. In addition, there will also be a comparison of the sustainability performance of conventional paper and LimeX using a simplified ProdSI. The study found that LimeX was marginally more sustainable than paper, but this evaluation could change with more information on the material.

Keywords: LimeX, product sustainability index, paper and plastic alternative

Requirements for the development of a performance management system with consideration of unforeseeable business process variants (ID X)

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Abstract: Supply chain issues arising from market turbulences force companies to find new solutions in the short term. Hence, deviations from the ideally designed processes are inevitable, especially during the execution of production planning and control. These deviations result in various unforeseen process variants. In addition, process steps of those process variants are often not completely conducted with IT systems and are therefore difficult to trace. Another underlying problem lies in the bias of performance measurement of different process variants because each variant aligns with different goals and framework conditions. For these and other reasons, the performance management of process variants presents a challenge. To overcome this challenge, requirements for the development of a performance management system with consideration of unforeseeable process variants are being developed on a use case basis and are presented in this paper. A serious game simulating the business processes and supply chain issues of a drilling machine manufacturer serves as the use case. The overarching goal is to further develop the serious game in such a way that trainings for performance management in a turbulent business environment can be provided.

Keywords: Performance Management System (PMS), Supply Chain Issues, Business Process Variants, Serious Game

Adoption of sustainability principles in product development & market discovery: A case presentation for building 'sustainability' habits in future workforce (ID X)

Liju George[1,2], Rohit Pillai[2], Veronika Marfina[1] and Gayathri A. Eranki[2]

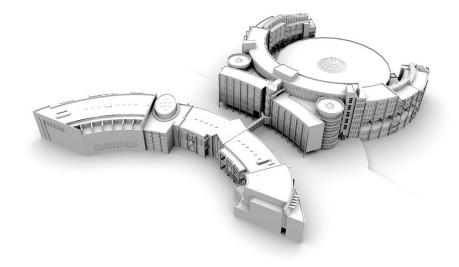*1* Alexander von Humboldt Stiftung
2 REAL Foundation

Abstract: This work presents experiences of applying the sustainability principles in product development and in market discovery in a rural enterprise context. It also explores the challenges that team/organisations face to apply sustainability principles in new venture creation process. It is understood that adoption of sustainability principles in fields of product/service design and in consumer behaviour is still low and limited to certain cases. One of the obstacle is discovering such avenues of application in products/service design and/or in consumer behaviour development requires contextual thinking and ability to operate under uncertainty. Lack of such skilled workforce also affects enterprises to adopt sustainability principles in new product/market development. Finally, this work proposes a method to address the gap in the workforce.

Keywords: -

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