GCSM

16th Global Conference on Sustainable Manufacturing

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Sustainable Manufacturing for Global Circular Economy

University of Kentucky
Lexington, KY USA

Abstract Book

IRP

University of Kentucky

ISM Institute for Sustainable Manufacturing

Technische Universität Berlin

Fraunhofer IPK

Preface

The Organizing Committee of the 16th Global Conference on Sustainable Manufacturing (GCSM) warmly welcomes you to the city of Lexington, KY, USA. This conference is jointly organized and hosted by the Institute for Sustainable Manufacturing (ISM) at the University of Kentucky, Technical University of Berlin IWF, and Fraunhofer IPK.

The GCSM serves as a forum for academics, researchers, and specialists from international universities, research institutes and industry working on topics related to sustainable manufacturing to share recent research advances and engage in intellectual dialogue. The conference includes keynote speeches by over a dozen prominent international researchers and industry leaders, panel discussions with industry leaders and Manufacturing USA Institute directors, and technical presentations in parallel sessions on current and emerging topics relevant to advancing Sustainable Manufacturing for Global Circular Economy. Within the theme of Circular Economy, technical presentations will focus on manufactured products, manufacturing processes and systems, and crosscutting technological topics including sustainable manufacturing education, innovation and technology development, and deployment. A total of over 135 papers will be presented in four parallel sessions for over 2.5 days. These papers are authored and co-authored by researchers/application specialists from over 34 countries representing all continents of the globe (North and South America, Europe, Asia, Africa and Australia), thus truly reflecting the true global nature of the conference.

A unique feature of this conference series is that it integrates *industrial engineering perspectives, sustainable manufacturing applications in emerging and developing countries, and education and workforce development for sustainable manufacturing*. This year's conference introduces a *special industry session* beginning with a keynote presentation and an industry panel, with *case studies and success stories in implementing sustainable manufacturing* presented by several industry groups. Also, a uniquely crafted and *moderated panel discussion session* with three directors and chief technology officers of *Manufacturing USA Institutes* will present the national and international strategic needs in sustainable manufacturing applied to topics of these institutes.

We welcome you to GCSM 2018 and look forward to your participation.

Best regards,

Prof. Günther Seliger
(Founding Chairman)

Prof. I.S. Jawahir
(Conference Chair)

Prof. Fazleena Badurdeen
(Conference Co-Chair)

Prof. Holger Kohl
(Conference Co-Chair)

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Table of Contents

Keynote Lectures

Keynote 1:
The Challenge of Sustainable Manufacturing

Günther Seliger

Professor and GCSM Founding Chair, Sustainable Manufacturing,
Technical University of Berlin, Germany

Abstract

The series of CIRP sponsored annual Global Conferences on Sustainable Manufacturing (GCSM) is coined by the spirit of coping with the challenge of sustainable manufacturing as fundamental means for value creation. Since 2003 thirteen different countries together counting for half of global population, 40 percent of global land, and almost 60 percent of global GDP have hosted these conferences under the local organization of respective local academic institutions with support of industry and civil initiatives. The complex interrelations of manufacturing technological means to cope with challenges of sustainability in economic, environmental and social dimensions have been considered under international perspectives in local national environment. Essential issues dealt with in 15 years of GCSM will be presented in an overview keynote presentation.

Keynote 2:
Using "Exponential" Technologies to Drive Manufacturing Towards a Sustainable Future

Dean L. Bartles

President, National Tooling and Machining Association
Founding Executive Director,
Digital Manufacturing and Design Innovation Institute, USA

Abstract

The manufacturing industry as we know it is fundamentally changing, with advanced technologies increasingly underpinning global competitiveness and economic prosperity. Many leading 21st-century manufacturers are converging digital and physical worlds in which sophisticated hardware combined with innovative software, sensors, and massive amounts of data and analytics is expected to produce smarter products, more energy efficient processes, and more closely connected customers, suppliers, and manufacturers. As growing numbers of manufacturing companies look to embark on this transformative journey and navigate through a maze of challenges and opportunities, executives— understandably—have questions: What exponential technologies show the most promise? What is the magnitude of impact that can be expected from adopting and deploying these exponential technologies? How is the manufacturing industry leveraging these technologies in new and distinctive ways to solve current business issues and/or transform our future? What does it really mean to become a Digital Manufacturing Enterprise (DME) of the future, and how might our business model evolve? How can we use these so called "exponential" technologies to drive our organizations towards greener manufacturing processes?

Keynote 3:
Towards Industrial Symbiosis in Discrete Manufacturing: Opportunities in Alternative Recycling Route Identification for Industrial Waste Streams

Joost R. Duflou

Head, Industrial Management Division, Traffic and Infrastructure,
Professor, Mechanical Engineering Department,
KU Leuven, Belgium

Abstract

In terms of resource efficiency strategy in discrete manufacturing, recycling production waste through conventional remelting techniques is often considered the only viable option. However, this approach still implies significant energy consumption and does not allow avoiding substantial material losses. Furthermore, it is no guarantee for material purity preservation. Alternative recycling routes, in which the waste output of one process is considered as potential input resource for other processes, are being studied. In this presentation, a series of examples will be reviewed that demonstrate how specific characteristics of waste streams, typically considered not desirable for conventional recycling purposes, can become assets when appropriate output-input matching can be achieved. The environmental impact that can be avoided by such an industrial symbiosis approach will be illustrated through some representative cases.

Keynote 4:
From Here to Circularity: A model for Restorative and Regenerative Enterprise

John Davies

Vice President and Senior Analyst, GreenBiz, USA

Abstract

The circular economy involves a fundamental rethinking of products, materials and systems of commerce. Most importantly, it will require new partnerships and alliances among business, government, and civil society. Approached correctly, circular business strategies can unleash an economic revolution that that is both restorative and regenerative. The challenge comes in driving these efforts to scale.

Mr. Davies will present examples of the challenges faced by businesses as they seek to transform current operations to take advantage of new opportunities. This will require innovative approaches to design, materials science, manufacturing, supply chain management, product strategy, logistics, procurement and other business functions. It will also require a new level of collaboration with customers, suppliers, and competitors as new business models and financing strategies evolve to support circular solutions.

Keynote 5:
Additive Manufacturing - A Game Changer for Sustainable Manufacturing?

Dermot Brabazon

Director, Advanced Processing Technology Research Centre at DCU
Deputy Director, I-Form Advanced Manufacturing Research Centre,
Dublin City University, Ireland

Abstract

Over the last decade in particular, improvements in Additive Manufacturing (AM) technologies have resulted in increased potential to directly print in one step functional components. In order to achieve this in produced parts, a number of important requirements have to be met such as a high-level dimensional accuracy, the availability of an improved range of functional materials, and a supply chain and cost model which is competitive with traditional manufacturing. In recent years, great strides have been made in these areas which enable a new range of applications to avail of AM technologies. The dimensional, physical and chemical integrity of polymer and metal printed parts have improved greatly allowing a broader range of end applications. There are now over 100 AM equipment suppliers which is mirrored by the increase in the materials supplied for these machines. Production speeds and quality control also continue to improve. The AM process has the ability to produce complex components with integrated functionality requiring less material and fewer production assembly steps. The raw materials for AM can be recycled, particularly for metal AM. The process can also be used to process parts in remote locations, with reduced need for transportation costs. In this talk, an overview of these developments and in particular their implications for sustainable manufacturing will be presented.

Keynote 6:
Manufacturing USA: Bridging the Gap to a Sustainable Future

Mike Molnar

Founding Director,
Interagency Advanced Manufacturing National Program
Chief, Advanced Manufacturing Programs,
NIST, USA

Abstract

A key challenge to restoring U.S. leadership in advanced manufacturing is building bridges across the so-called "missing middle" – the technical and business barriers of scaling-up (and speeding up) an innovative new material, process, or technology for robust production use. The Manufacturing USA program is now in its fourth year with 14 innovation institutes. Each institute is a federally sponsored public-private partnership designed to accelerate U.S. innovation through applied research and advanced workforce skills development. These manufacturing institutes are places where industry and academia partner on industry-relevant challenges. This presentation provides an overview of the program, explains how an institute works, and covers recent highlights along with developments ahead. To illustrate institute operations, the REMADE institute on sustainable manufacturing will be profiled.

REMADE, short for Reducing Embodied Energy and Decreasing Emissions, focuses on materials manufacturing and energy efficiency. In partnership with industry, academia, and national labs, the REMADE Institute enables early-stage applied research and development of technologies that could dramatically reduce the embodied energy and carbon emissions associated with industrial-scale materials production and processing. Efficiencies gained from these technologies have the potential to save billions in energy costs, improve U.S. economic competitiveness through innovative new manufacturing techniques, and offer new training and jobs for American workers.

Keynote 7:
International Case Studies for Innovative Learning Approaches by Learnstruments and MakerSpaces for Fostering Sustainable Manufacturing

Holger Kohl

Vice-Director,
Fraunhofer Institute for Production Systems and Design Technology IPK
Director, Division Corporate Management,
Fraunhofer Institute for Production Systems and Design Technology IPK
Professor, Sustainable Corporate Development,
Technical University of Berlin, Germany

Abstract

The fast and disruptive changes in global value creation networks towards highly digital integrated production environments and the growing challenge of sustainability are setting new demands on engineering education. Meeting the future needs for teaching, learning and in-work training requires the development of new learning conducive technologies, approaches and intercultural soft skills.
To address these challenges, a perspective of problem- and experience-based teaching and learning in industrial engineering as a tool in research and education is given. A morphology for the structure of Learnstruments and exemplary learning-conducive applications are presented. Furthermore, it is shown how MakerSpaces can be used to rapidly develop and manufacture these Learnstruments as well as prototypes for study courses related to sustainable manufacturing and entrepreneurship.

Keynote 8:
Towards Sustainable Energy: Advancing Solar PV in Harsh Desert Climates

Marwan Khraisheh

Senior Research Director, Hamad Bin Khalifa University, Qatar Foundation, Qatar

Abstract

Climate change and energy security are undoubtedly among the most pressing challenges the world faces today. It is critical to adapt sustainable and energy efficient technologies and practices and rely more on renewable energy. Despite recent advancements in the utilization of solar energy as an efficient and sustainable source of energy, major obstacles facing deployment of large solar farms regions still exist. For example, desert-like climates face major challenges such as excessive heat and the presence of soiling which drastically impact the efficiency of solar PV. The first part of the presentation will identify these challenges and highlight the recent research efforts undertaken by researchers at Hamad bin Khalifa University (HBKU) at Qatar Foundation to find innovative solutions. Additionally, another major challenge facing widespread utilization of solar energy is its unpredictable nature making it difficult to correlate with energy demand profiles for optimum use. The second part of the presentation will focus on a prediction algorithm correlating solar PV energy production with demand profiles using support vector machines technique. The algorithm, capable of one-day ahead forecasting of PV output and load profiles, is validated using one-year data collected from a PV array, a weather station and sensors measuring energy consumption.

Keynote 9:
Integrated Decision-Making for Sustainable Design and Manufacturing

Rossi Setchi

Professor and Director, Cyber-Physical Systems Programs,
Cardiff University
Leader, High-Value Manufacturing Research Group,
Cardiff University, United Kingdom

Abstract

This talk highlights the main challenges in industrial sustainability from the point of view of the decision makers and the importance of having computational tools to compare alternatives in terms of cost and environmental implications. The talk presents an eco-design decision-making methodology that integrates life cycle assessment, process modelling and quality function deployment and provides opportunities to consider alternatives at different stages of product design. All product sustainability considerations are conducted within a special eco-design house of quality. This brings together the analysis of factors relating to manufacturing processes, product usage and end-of-life strategy; it insures that product sustainability is central to any design development and that the implications of change are fully identified and justified. The talk will demonstrate the complexity of the decision-making process and the need for knowledge-based and semantic tools to support the decision-making process.

Keynote 10:
The Great Convergence: Biologicalization, Digitalization, Sustainability and Future Manufacturing

Rafi Wertheim

Professor, Fraunhofer IWU Chemnitz, Germany

Abstract

Bio-intelligent value adding bears potential for disruptive innovations in manufacturing. As a possible combination of digital and biological transformation, it may significantly change the design and handling of production processes and products. Biological transformation is considered as a new emerging frontier in the evolution of digitalization and the Fourth Industrial Revolution (Industry 4.0). The principle of biologically inspired intelligent manufacturing is proposed to be a driver and factor for sustainable development of new materials, design concepts, processes and equipment as well as production systems. The potential of utilizing biological principles can be considered for innovative lightweight environmentally friendly and energy efficient industrial products, mainly by using, being inspired by or by imitating biological elements, solutions, phenomena, materials, or living creatures. The combination of biological principles with digitalization, new technologies and new processes provides an excellent tool for sustainable and resource efficient production. This keynote paper includes the latest findings of a major Fraunhofer analysis on possible scenarios, fields of action, potentials, and demand of a biological transformation of the manufacturing industry and a groundbreaking review from the international Academy for Production Engineering (CIRP), introducing the principle of biological transformation in engineering. It presents and discusses examples of research and development directions such as additive manufacturing as well as industrial products.

Keynote 11:
Digitized, Optimized, Ecologized? Can Digitization Promote Sustainable Manufacturing?

Wilfried Sihn

Academic Director,
Transnational MBA 'Automotive Management', TU Wien
Managing Director, Fraunhofer Austria Research GmbH
Head, Industrial and System Engineering Department,
TU Wien, Austria

Abstract

Digital representations of production systems are a powerful way to achieve optimized operations. This is especially true when not only economic, but also ecological goals are to be pursued, with a sustainable production.
This keynote will present an insight into approaches utilizing a simulation-based optimization of production systems and the potential of such planning methods concerning energy and resource efficiency, plus the chances and challenges against the backdrop of the ongoing energy transition. The effect of temporal aspects – i.e., different planning horizons from short-term to long-term planning, as well as different levels of the synchronization frequency of digital representations with the corresponding real-life systems, will be explored.

Keynote 12:
Smart Manufacturing of Natural Fiber Composites

Mohamed El-Mansori

Professor and Director, Materials Processing Labs, Arts et Métiers Paris Tech, France

Abstract

Natural fiber reinforced plastic (NFRP) composites are attractive materials for sustainable manufacturing since natural fibers are renewable, have low production cost, low density, and high in-service performance. These characteristics enhance energy efficiency, minimize negative environmental impacts, and promote a circular economy. To further improve the sustainability of NFRP manufacturing in terms of energy efficiency, especially during the machining step, it is necessary to perform an in-depth energy investigation during the cutting operation that should consider the multiscale structure of natural fibers inside NFRP composites. This talk presents the work of the authors in smart manufacturing of NFRP composite materials, as well as the implications of their approach in gaining a better understanding of the cutting energy contribution of each NFRP component and to the optimization of the energy dissipated during the process.

Luncheon Speakers

Lecture 1:
Global Sustainable Development Goals - An Obligation for All of Us!

Ömer Şahin Ganiyusufoğlu

Chairman, Corporate Members Advisory Group (CMAG),
International Academy for Production Engineering (CIRP)
Consultant to Chairman,
Shenyang Machine Tool (Group) Co., Ltd., China

Abstract

In our daily life we get plenty of news about political and economic issues, sports, cultural events, but also about poverty and natural disasters. We spend too much time dealing with daily issues instead of thinking about the background of poverty and national disasters. In our western world, we enjoy a prosperous life without being aware of what are the consequences of our high living standard and our wastefulness. Academic studies show that the way of our living style will lead to a disastrous future. We will consume the resources, we will damage the environment and we will destroy eco-systems. We all do not take notice of these facts. In 1987, the United Nations, after comprehensive studies, took an initiative, and defined 17 Sustainable Development Goals (SDGs) for preventing our earth and the mankind from further damage. In this presentation, the SDGs will be introduced and how the SDGs could be put into reality will be presented. Furthermore, proposals will be made on how each of us could contribute to SDGs in daily life by simple changes in our life style.

Lecture 2:
Circular Economy and the Ellen MacArthur Foundation

James George

Business Development Lead, Ellen MacArthur Foundation, UK

Abstract

The Ellen MacArthur Foundation's (EMF) mission is to accelerate the transition to the circular economy. Looking beyond the current "take, make and dispose" extractive industrial model, the circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to design waste out, while minimizing negative impacts. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital. EMF's five interlinking focus areas include: Learning - developing the vision, skills and mindsets needed to transition to a circular economy; Business and Government - catalyzing circular innovation and creating the conditions for it to reach scale; Insight and Analysis - providing robust evidence about the benefits and implications of the transition; Systemic Initiatives - transforming key material flows to scale the circular economy globally; and Communications - engaging a global audience around the circular economy. In this talk, the EMF guiding principles will be explained via a series of examples that will illustrate how the circular economy works with manufacturing, products, business models and innovation.

Session 1: Sustainable Products -
Product (Re)Design for Circular Economy

Quantitative Risk Modeling for Evaluating Sustainable Product Designs

Christian Enyoghasi[a,b,*], Adam Brown[b], Ridvan Aydin[b], Fazleena Badurdeen[a,b]

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[b]*Institute for Sustainable Manufacturing, Lexington, KY, 40506, United States*
**enyoghasi.christian@uky.edu*

Abstract

A major setback to sustainable product design is the lack of an effective method to evaluate the effect of various risks on its total lifecycle sustainability performance. Most risk management methods are qualitative in nature, making them unsuitable to fully capture the interdependencies between risk events. In this paper, we propose a methodology for identifying sourcing, manufacturing, supply chain and other risks related to a product design and developing a risk network map to capture the interdependencies between these risks. A Bayesian Belief Network-based method is employed to quantitatively model and conduct risk sensitivity analysis on the total lifecycle sustainability performance. An industrial case study is conducted to evaluate the sensitivity of total lifecycle cost, GWP, water and energy use to risks related to a toner cartridge design. The proposed methodology helps evaluate the sensitivity of product design performance to various risks.

Integrated Additive Product Development for Multi-Material Parts

Jerome Kaspar[a,*], Stephan Bechtel[b], Tobias Häfele[c], Franziska Herter[d], Jan Schneberger[a],

Dirk Bähre[d], Jürgen Griebsch[c], Hans-Georg Herrmann[b,e], Michael Vielhaber[a]

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[b]*Chair for Lightweight Systems, Campus E3 1, 66123 Saarbrücken, Germany*
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[d]*Institute of Production Engineering, Saarland University, Campus A4 2, 66123 Saarbrücken, Germany*
[e]*Fraunhofer Institute for Nondestructive Testing IZFP, Campus E3 1, 66123 Saarbrücken, Germany*
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Abstract

Current resource and energy requirements call for the use of most beneficial materials with suitable design at the right place as well as appropriate manufacturing technologies and associated process chains. Additive manufacturing (AM) can play a key role for prospective multi-material components, particular with its versatile advantages in design-driven flexibility, customization, and lightweight design. However, obstacles to industrialization are less due to the technology itself rather than to the actual process chain integration, from conception to production and testing.
Accordingly, this contribution discusses an application example and arising problems with the integration of AM in product development. The authors highlight the most demanding steps of tailored constructive development methods, efficient manufacturing, post-processing and finishing as well as quality and lifetime management by continuous non-destructive testing.

A Total Life Cycle Approach for Developing Predictive Design Methodologies to Optimize Product Performance

Buddhika M. Hapuwatte*, I.S. Jawahir

Institute of Sustainable Manufacturing (ISM), Department of Mechanical Engineering, University of Kentucky, Lexington, KY, 40503 US
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Abstract

Sustainable products must be designed by considering how design decisions impact their total life cycle (TLC) sustainability content. Even more so important when designing products to incorporate the technological elements of sustainable manufacturing, the 6Rs (Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture), to achieve Circular Economy (CE). This paper presents the preliminary work of an ongoing research project on developing a novel framework incorporating predictive models with TLC considerations. This unique approach develops and integrates models with associated risks, and optimizes for maximizing the sustainability benefits due to design decisions. Such predictive capability is extremely useful for process planning, where careful planning and optimization of process conditions would allow inducing favorable product performance and improved sustainability.

Constructive Methods to Reduce Thermal Influences on the Accuracy of Industrial Robots

Christian Mohnke[a,*], Sascha Reinkober[a], Eckart Uhlmann[a,b]

[a]*Fraunhofer Institute for Production Systems and Design Technology IPK, Pascalstraße 8-9, 10587 Berlin, Germany*
[b]*Institute of Machine Tools and Factory Management, Pascalstraße 8-9, 10587 Berlin, Germany*
**Christian.mohnke@ipk.fraunhofer.de*

Abstract

Due to their kinematics and their mobility, industrial robot systems offer a flexible, adaptable basis. An influencing variable, which is particularly relevant for processes with long process times, is the thermal heating and the associated thermal drift of the tool center point. The maximum deviation from the actual nominal position can reach up to 1.5 mm.
To counteract these displacements, a cooling strategy or a targeted preheating can be installed. Both possibilities were evaluated under constructive, energetic and economic aspects and implemented on at least one axis of an industrial robot. Furthermore, a structural thermal decoupling and optimized design of the respective components were carried out. The results can help to reduce the influence of thermal heating and the associated thermal drift of the TCP by structural support without using cost-intensive measures with additional hardware and software on external computers for compensating the errors.

Demand-oriented Barriers and Potentials for Remanufacturing in Vietnam

Guidat, T.[a], Wewer, A.[a,*], Kohl, H.[a,b], Seliger, G.[a]

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Abstract

Since the liberalisation of its economy, Vietnam imposed as a key location for investment in workforce-intensive assembly processes operation, through an available and cheap workforce. Soaring national consumption levels for goods and services generate in turn unprecedented quantities of waste to be treated locally. In 2015, governmental decision 16/2015/QĐ-TTg set basis for a national waste legislation for mechanical and electronic equipment goods. Remanufacturing is a non-destructive, industrial reuse strategy which aims at restoring products to original specifications by reusing a maximum number of original components in their current form. It has potential to provide Vietnam with an alternative to low value-added repair activities. As Vietnam is the fourth market for motorcycles in the world, this paper presents a case study about barriers and potentials for remanufacturing from the market and customer perspective. Potential solutions for supporting industrial development are suggested.

Session 2: Sustainable Manufacturing Processes -
Manufacturing Processes, Tools and Equipment

Investigating the Microstructure and Morphology of Chips in Dry, Flood Coolant and MQL Machining of Ti-6Al-4V Alloy

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Abstract

The objective of this research is to investigate the morphology and microstructure of the chips formed during milling of Ti-6Al-4V alloy using conventional flood coolant and sustainable dry and MQL machining conditions. The chips were found to be serrated in nature irrespective of the machining conditions. It was found that the chips formed in dry and flood coolant machining had burrs on the edges indicating possible burr formation on the machined slots. Ti-6Al-4V alloy chips, which had a bi-modal structure before machining, remained the same in the bulk part of the chips. However, phase transformations were seen for all three machining conditions at the shearing plane of the chips. It was found that the chips formed in dry machining had comparatively higher percentage of b-phase due to phase transformation. For the chips obtained in flood coolant machining, the transformed bphase possibly returned to martensitic a-phase due to rapid cooling. The MQL machined surface had the least transformation of bphase, indicating minimal changes in mechanical properties of the machined parts in sustainable MQL machining.

Sustainability of Friction Stir Welded AA6082 Plates through Postweld Solution Heat Treatment

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Abstract

There is high demand for a novel fabrication technique that requires low energy consumption rate for its operation, environmentally friendly and sustainable. The aforementioned attributes make friction stir welding (FSW) to be globally accepted in joining aerospace alloys that are difficult to weld using the conventional arc welding technique. In this investigation, friction stir welds were processed plastically and characterized thermo-mechanically. Also, three welding speeds i.e. 90 mm/min, 120 mm/min and 150 mm/min were adopted using tool-rotational speed 950 rpm and 1150 rpm respectively. An attempt was made to investigate the effect of severe plastic deformation and solution heat treatment on the tensile property of the welds. A solution heat treatment temperature of 4700C for 30minutes, held for 30 another minutes and water quench. The mechanical properties of the welded joints after solutionizing was linked to the sustainability of FSW process. A maximum tensile strength (UTS) of 100 MPa for the as-weld specimen and 233.5 MPa after post-weld heat treatment were recorded at welding parameter 150mm/min and 950 rpm

respectively. Meanwhile, the higher the weld-pitch (mm/rev) and the heat input (J), the softer the weld joints and the lower the UTS. Aside from point of fracture which were observed to be at the thermo-mechanical zone (TMAZ), the disparities in composition evolution and physical features of all the welded joints were similar. In conclusion, solution heat treatment improved the weld strength as well as the ductility. The improved value of UTS through solution heat treatment makes the weld joints reliable and FSW a sustainable process.

Road Map to Sustainability of Friction Stir Welded Al-Si-Mg Joints Using Bivariate Weibull Analysis

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Abstract

Welding is a crucial joining technique that is generally embraced in the fabrication industry. The integrity of weld joints is of great importance because of its safety and economic importance. In this paper, the concept of reliability as it applies to FSW was introduced to reduce repair and maintenance cost. The Friction stir welding (FSW) of Al-Si-Mg alloy was examined. The response of welding parameters on joints integrity was assessed through Weibull analysis of weld strengths. The analysis revealed that the Weibull modulus increases with FSW parameters and 120mm/min welding speed gave the highest value while the 90mm/min speed gave the least. Meanwhile, the reliability of welds was observed to reduce by approximately 30% as the traverse speed increases by 25%. This was due to the presence of defects and recrystallization of the grain morphology. The higher the weld joint reliability the better the sustainability.

Performance Assessment of CaF_2 Solid Lubricant Assisted Minimum Quantity Lubrication in Turning

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Abstract

Machining is one of the most widely used manufacturing processes and conventional cutting fluid have been used in large quantity to tackle the effects of heat generated during metal cutting. Looking at the effects of the cutting fluids on the environment as well as an increase in total production cost, the performance of CaF_2 solid lubricant assisted minimum quantity lubrication in turning is studied. The performance of solid lubricant is judged by measuring surface roughness, chip-tool interface temperature and tool flank wear in different machining conditions. The effect of different concentration of solid lubricant is analyzed under various cutting conditions. A

comparison of the results is provided with that of obtained in dry, wet and minimum quantity lubrication (MQL) machining. The results indicate the improvement in process performance with the application of solid lubricant assisted lubrication. The use of the solid lubricant with MQL can be considered as a low-cost environment-friendly alternative.

A Fracture Mechanics Approach to Wire Design for Reduced Damage in Diamond Wire Sawn Silicon Wafers

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Abstract

By decreasing the subsurface damage in silicon wafers produced by diamond wire sawing, the amount of silicon to be etched in subsequent wafer manufacturing steps can be minimized, leading to a more sustainable wafer manufacturing process. In addition to the sawing process parameters, the subsurface damage is influenced by the design of the diamond wire. This paper presents a fracture mechanics approach for the design of a fixed abrasive diamond wire used in wire sawing of silicon wafers. Starting from an allowable damage (crack) depth, indentation fracture mechanics and contact analysis are used to determine the wire design parameters, namely the grit protrusion and peripheral distribution of the diamond abrasives.

Session 3: Sustainable Manufacturing Systems -
Energy Efficiency in Manufacturing Systems

Energy Flexibility – A new Target Dimension in Manufacturing System Design and Operation

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Abstract

Decarbonizing the energy system by integrating increasing shares of intermittent energy sources from solar and wind requires the development of demand response mechanisms. In the following an approach is introduced on how energy flexibility can be considered as an operational target in the planning and optimization of manufacturing system. For this purpose, an extension of the Logistic operating curves is introduced in order to quantitatively assess correlations between productivity and energy consumption to provide energy flexibility and enabling companies to evaluate their products' environmental impacts. For evaluation purposes, a case-study was conducted in the manufacturing industry. The results underline the necessity for decision makers in manufacturing to consider energy flexibility in their medium to long term strategic decisions.

Strategic Energy Management in Mechanical Series Production: An Industrial Use-Case

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Abstract

In recent years, the automotive industry has set ambitious goals to reduce CO2 emissions of production facilities and started to consider energy costs in strategic procurement of manufacturing systems. Based on an industrial use-case, energy and media consumption behavior of production lines for series production of powertrain components was characterized and the degree of energetic utilization of machines and peripherals was evaluated. Technical and organizational efficiency measures were identified and benchmark KPIs were defined. In order to allow for demand forecasting as well as an evaluation of optimization strategies, material flow models of the production lines were extended by energy and media consumption data. Thus, demand-oriented operation of given infrastructure in different production scenarios as well as optimal dimensioning, design and control of new infrastructure was facilitated. Finally, a monitoring system based on an aggregation of continuously recorded sensor and production control data was established, allowing for continuous target-actual KPI comparison.

Dynamic Design and Management of Reconfigurable Manufacturing Systems

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Abstract

This research proposes an approach to design and to manage Cellular Reconfigurable Manufacturing Systems (CRMSs) from a multi-product and multi-period perspective. The production environment consists of multiple cells of machines equipped with Reconfigurable Machine Tools (RMTs) made of basic and auxiliary custom modules to perform specific tasks. The approach acts into two steps; the former is the machine cell design phase, assigning machines to cells, the latter is the cell loading phase, assigning modules to each machine and cell. The goal is to guarantee the economic sustainability of the manufacturing system by exploring how to best balance the part flow among machines already equipped with the required modules and the effort to install the necessary modules on the machine on which the part is located.

Simulation-Based Analysis of Energy Flexible Factories in a Regional Energy Supply System

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Abstract

In a decentralized and renewable energy system, reliable and economical solutions are necessary to adjust power demand to a volatile power supply by photovoltaic and wind energy plants. A high potential for the balancing of short and medium-term power supply fluctuations is seen in energy flexible factories. To leverage this potential, monetary incentives and technological enablers have to be developed. Apart from that, the ecological and social aspects of energy flexible factories have to be considered in transdisciplinary research, to achieve a broad public acceptance. To assess the complex interrelations between the technical, political, legal and social sector, a clear and accessible base for discussions is necessary. This paper presents an approach for a simulation based-analysis of energy flexible factories with focus on high applicability and comprehensibility for stakeholders from different disciplines. This paper presents the general structure of the simulation model including the operation module for the energy flexible region Augsburg.

Methodology for the Sustainability-related Evaluation of Human-Robot Collaborations

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Abstract

The various challenges of a sustainable industrial production such as demographic change and resource scarcity induce the increasing need of a resource-efficient, eco-friendly, flexible and adaptive production with human-centered and ergonomic suitable working stations and conditions. The novel production approach of human-robot collaboration promises to contribute to meeting these requirements. Nevertheless, for designing and realizing concrete applications, a significant evaluation comprising the economic, ecological and social dimensions of sustainability is needed. The paper presents a methodology for such evaluations of human-robot collaboration with respect to their contribution to sustainability. Additionally, the application of the methodology is illustrated by assessing a human-robot collaboration solution in a concrete industrial use case.

Session 5: Sustainable Products -
Product (Re)Design

Conceptual Model of Life Cycle Assessment Based Generic Computer Tool towards Eco-Design in Manufacturing Sector

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Abstract

Even though life cycle assessments (LCA) provide a complete environmental performance analysis and guide to eco-designs, complexities have slowdown the distribution of LCA methodology in manufacturing sector. Even bottom level advanced LCA computer applications like SimaPro and Gabi are available, it limits to the research level and not popular in industry. A comprehensive research work is needed to develop life cycle inventory (LCI) under complexities such as data collection, scenario identification, allocation, aggregation and data quality measurements. During life cycle impact assessment (LCIA) with advanced
LCA software, linking with international databases makes severe challenges such as clearly identification of secondary life cycles, selection of appropriate datasets and dataset modifications. An analytical interpretation of impact categories can be used to identify environmental hotpots and provide eco-design capabilities. Proposed conceptual computer application is addressed to cross the long barrier between raw data feeding and eco-design assistance. A strong LCA based, industry specific, Industrially Generic, eco-design guided, user friendly and real time DSS tool motivates industrialists to move towards sustainable manufacturing.

Development of an Electric Drive Train for Cycles as a Sustainable Means of Transportation for a Green Environment

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Abstract

A reliable and sustainable means of human transportation is vital for the world's increasing pollution emissions and congestions on the motorways. The research aimed at and focused on developing an affordable electric drive train for cycles using the principle of Continuously Variable Transmission (CVT) to provide an interminable number of speed ratios by varying the pulley diameters. The planetary gears designed and installed within the CVT chamber provided a locking mechanism for the ring gear to provide forward transmission to the rear wheel where motion was

stepped up through an open differential gear to propel the cycle forward. For stability and ease of manufacture and assembly, a tricycle concept was chosen and developed as a sustainable and alternative means of transportation. The developed electric drive train provides a 'green' and affordable means of human transportation in a world geared towards the elimination of pollution.

Stepping Valve Actuator Algorithm for a Camless IC Engine

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Abstract

Camless Engines offer many advantages over poppet valve systems. However, they suffer from air/hydraulic leakages and piston-valve interactions. In addressing the situation, the stepping valve rotates perpendicularly to the piston motion with no interactions. In this case, the valve events will be flexible enough to allow engine cranking without the mechanical starter. For this study, a 3-phase, 12-coil Stator rated at 3Amp 12V DC and a Stepping Valve were used. To avoid friction against its seat, the Stepping Valve is lifted up by 1mm in 2mS. Then it steps to a new Valve State Position in 2mS before gently landing back on its seat in 4mS. The Valve Event Algorithm has been designed, simulated and successfully programmed onto an Altera Programmable Device using Max Plus II Design Environment. The overall aim of this study is to have the three components required for ignition: fuel, spark and air, entirely controlled in software to maintain engine efficiency for the entire RPM range.

A Study on the role of Oil-Air Mist Lubrication on a Ultrahigh-Speed Bio-Generator

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Abstract

The significance of economical exploitation of resources has brought a need for compact and efficient electromechanical systems and electrical machines. The electrical machines such as bio-generator need to be featured with high power densities and high efficiencies with lower excitation losses, magnetizing currents and rotor losses. However, the research progress has often been challenged by the ultrahigh-speed bio-generator knowhow as the design must be dealt with factors: i) "DN" rating of value ~ 1.5X 106 and above ii) high value of "kW/speed" rating. Furthermore, the thermal management of ultrahigh-speed bio-generator is difficult and complicated as the temperature rise in high-speed bio-generator facilitates demagnetization cascading to the reduction of the output power. The output of research portrays the use of pressurized oil-air particles as a lubrication method on an ultrahigh speed bio-generator to avoid: thermal damage and starvation at the rolling element and to address the predominant concern which is effective cooling of ultra-precision ball bearings even at elevated speeds. The ultrahigh-speed generator was designed and developed to operate at a maximum speed of ~30000 RPM to deliver 10kW output power and expected to 80 ~ 92°C temperature rise with ~2 kW idle power

consumption enough to cause a severe impact to the rolling elements of the bearing. The newly developed oil-air mist lubrication arrangement enables to control the temperature rise at the rolling element and ensures the use of ultrahigh speed conditions for the bio-generator.

Session 6: Sustainable Manufacturing Processes -
Additive Manufacturing

Improving Sustainability and Cost Efficiency for Spare Part Allocation Strategies by Utilisation of Additive Manufacturing Technologies

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Abstract

Currently, no proper cost models are available to assist managers in selecting part-specific allocation strategies for spare parts under consideration of metal additive manufacturing (AM). Therefore, sustainability aspects and cost efficiency over a product lifecycle show potential for optimisation. The aim of this paper is to propose a two-stage model as a basis for decision support in spare part allocation.
The first stage introduces a multi-criteria part classification regarding classical criteria as well as criteria referring to AM. The impacts on different spare part allocation strategies like final stockpiling, conventional spare part production or AM on demand will be focused.
Based on the first stage, a conceptual model for a comprehensive activity based cost assessment will be adopted to assess the arising costs that occur for each of the compared allocation strategies. Evaluating the relevant factors for the specific product, process, warehousing and capital issues, the basis for choosing the best suitable spare part allocation strategy will be presented. The present document is a working paper, where the interim results of the intended concept model are introduced.

Improving the R&D Process Efficiency of the Selective Laser Sintering Industry through Numerical Thermal Modeling

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Abstract

The selective laser melting (SLS) industry is a relatively novel industry within the broad spectrum of available additive manufacturing (AM) technologies. As with most developing industries, the primary aim is to develop better quality components at reduced costs, often with a disregard towards efficiency. Resource efficiency is a key component of waste management and ties directly to sustainable manufacturing. In the SLS industry large quantities of raw material are wasted during the machine calibration stage. Each time a new material is developed for SLS manufacturing, a specific set of processing parameters need to be developed in order to ensure that high density, high strength components are produced. This paper investigates the possibility

of replacing the current inefficient research and development (R&D) methods with numerical modeling. The fusion process can be simulated in a numerical thermal model using a combination of temperature dependent material properties and heat transfer principles.

Sustainability of Metal Powder Additive Manufacturing

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Abstract

Additive manufacturing, or 3D-printing, has attracted attention and raised expectations regarding future production and repair of parts, for example, in the aerospace industry. Various techniques have been utilized to deposit metal alloys for components. It has been suggested that this may offer great benefits in terms of sustainability, in particular, new opportunities for lightweighting. There are, however, outstanding questions about sustainability benefits outside of the use phase. In this paper, the material and manufacturing life-cycle stages were investigated for details produced using INCONEL 718. Energy measurements from an ARCAM A2X Electron Beam Melting system are presented and compared to the embodied energy and indirect CO2-emissions of the feedstock as well as to traditional subtractive manufacturing. It is found that both the metal powder production and the additive manufacturing process itself contribute considerably to total energy use and emissions. Ashby's 5-step method for assessment of sustainable development is used to briefly discuss economic and social implications of additive manufacturing.

Optimisation of Build Orientation to Achieve Minimum Environmental Impact in Stereo-Lithography

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Abstract

Additive Manufacturing includes a number of techniques that combine a specific equipment with certain materials but some common principles concerning the product design and aspects related to manufacturing optimisations can be identified. Amongst these principles, some process parameters are included that contribute to determining the environmental sustainability of engineering products and, in particular, that affect their Life Cycle Impact Assessment.
This paper aims to provide a method to find out build orientation for the additive stereo-lithography process by minimising the environmental impact. More precisely, environmental indicators related to product design, materials and machines are included and combined in order to estimate the process time and the volume of needed supports. Besides, Genetic Algorithms have been used to find out the product orientation that optimises the manufacturing process in terms of quantity and volume of used material, thus minimizing its environmental impact. The proposed method has been implemented by a new software application that is presented in a nutshell.

Guidelines to Compare Additive and Subtractive Manufacturing Approaches under the Energy Demand Perspective

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Abstract

In order to characterize the environmental performance of Additive Manufacturing processes, comparative analyses are required. Different manufacturing approaches (such as additive and subtractive ones), besides adopting different equipment, use different kinds and amounts of material. Therefore, the material-related flow has to be followed throughout the entire product life. Differences in environmental impact arise at each step of the life cycle: material production, manufacturing, use phase, disposal, and transportation. In this paper, a life cycle-based methodology able to take due account of all the factors of influence on the total energy demand for the production of metal components is given. Decision support tools for identifying the most sustainable manufacturing route (subtractive versus additive manufacturing-based approaches) are presented for different scenarios. The aim of the paper is to contribute to the debate concerning the environmental impact characterization of Additive Manufacturing processes.

Session 7: Crosscutting Topics in Sustainable Manufacturing - Strategies and Business Models

Benchmarking the Sustainable Manufacturing Paradigm via Automatic Analysis and Clustering of Scientific Literature: An Italian Technologist Perspective

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Abstract

The number of scientific papers in the field of Sustainable Manufacturing (SM) shows a strong growth of interest in this topic in the last 20 years. Despite this huge number of publications, a clear statement of the profound meaning of Sustainable Manufacturing, or at least a strong theoretical support, is still missing. The 6R framework seems to be a first attempt to rationalize this issue, as it is an axiomatic identification of its true nature. Recognizing the pursuing of one or more of the Reduce-Recycle-Reuse-Recover-Redesign-Remanufacture principles allows users to identify if any manufacturing action is in the right direction of sustainability. In the paper, the authors speculate on the use of this framework and its possible extension by referring to all the existing scientific contributions on Sustainable Manufacturing in the SCOPUS® databases as a source of data. Starting from the measurement of the distribution of the scientific papers allocated onto the 6Rs dimensions, by using both author keywords and automatically extracted multiword from texts, the distribution of the scientific papers among the 6R was derived. A new framework is proposed based on analytical text tools to compare the affinity of the applied research activities of the Italian Technologist network SOSTENERE to sustainable manufacturing and provide also a benchmarking view to describe the Italian way to SM with respect to the rest of existing applications.

A Conceptual Framework to Create Shared Value in Base of the Pyramid Communities with Micro-Containerised Factories

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Abstract

Shared value creation at the Base of the Pyramid (BoP) receives growing interest. The BoP is a socio-economic group characterized by people who have poor nutrition, limited income, inadequate technologies, lack of access to markets and poor infrastructure to produce valuable products and services. Possible methodologies and systems to successfully implement sustainable microcontainerised factories at the BoP are still very limited and remain unanswered. In this study a conceptual framework to create shared value in BoP communities with micro-containerised factories is developed. These factories provide portable, scalable technologies to produce valuable products from sustainable locally sourced resources or waste streams. Concepts from literature and case studies were evaluated to identify key elements for the conceptual framework.
A proposed business model and conceptual framework were developed to guide business model prototyping on a case study in South Africa.

Designing and Redesigning Products, Processes, and Systems for a Helical Economy

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Abstract

The Circular Economy (CE) concept has promised to unlock trillions of dollars in business value while driving a significant reduction in the world's resource consumption and anthropogenic emissions. However, CE mainly lives in ambiguity in the manufacturing domain because CE does not address the changes needed across all of the fundamental elements of manufacturing: products, processes, and systems. Conceptually, CE is grounded in the concept of closed-loop material flows that fit within ecological limits. This grounding translates into a steady state economy, a result that is not an option for the significant portion of the world living in poverty. Therefore, this paper proposes the Helical Economy (HE) concept as a novel extension to CE—one that allows for continued innovation and economic growth by leveraging an Internet of Things (IoT) infrastructure and by reimagining products, processes, and systems.
This paper intends to be the conceptual overview and a framework for implementing Helical Economy in the manufacturing domain.

Using the Sharing Economy Approach to Provide Sustainable Mobility

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Abstract

Mobility is an essential human need that everyone should have access to. However, not only providing mobility but also providing sustainable mobility represents of the biggest challenge worldwide. Increasing CO2 emissions, poor air quality, and noise pollution are some of biggest problems caused by mobility products, especially in urban areas.
Furthermore, limited parking space and traffic jam are often hindering individual mobility. Providing public transportation for everyone can help to solve these problems. However, not all mobility needs can be provided through public transport economically. Another option of providing mobility is based on the Sharing Economy Approach. Using the Sharing Economy Approach individuals do not have to make considerable investments for mobility e.g. a car, but can use readymade mobility products tailored for their needs. Not only the design for the individuals need but also the possibility of a sustainable design constitutes a major advantage compared to current individual mobility. Sustainable mobility concepts based on the Sharing Economy Approach combined with public transportation are the key for providing sustainable mobility for metropolitan areas. This paper provides possible solutions and a student case study on how the Sharing Economy Approach for electric scooters can contribute to sustainable urban mobility.

Non-linear Autoregressive Neural Network (NARNET) with SSA Filtering for a University Energy Consumption Forecast

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Abstract

Energy consumption forecast is essential for strategic planning in achieving a sustainable energy system. The hemispherical seasonal dependency of energy consumption requires intelligent forecast. This paper uses a non-linear autoregressive neural network (NARNET) for energy consumption forecast in a South African University with four campuses, using three-year daily energy consumption data. Singular Spectrum Analysis (SSA) technique was used for the data filtering. Three window lengths (L=54, 103 and 155) were obtained using periodogram analysis and R-values of network training at these window lengths were compared. Filtered data at L=103 gave the best R-values of 0.951, 0.983, 0.945 and 0.940 for campus A, B, C, and D respectively. The network validation and a short-term forecast were performed. Forecast accuracies of 85.87%, 75.62%, 85.02% and 76.83% were obtained for campus A, B, C and D respectively. The study demonstrates the significance of data filtering in forecasting univariate autoregressive series.

Session 9: Sustainable Products -
Product Recovery, Reuse and Remanufacturing

Solving the Disassembly-to-Order Problem for Components and Materials under Stochastic Yields, Limited Supply, and Quantity Discount using Linear Physical Programming

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Abstract

In order to save consumption of natural resources, it requires a disassembly-to-order (DTO) system where end-of-life (EOL) products are purchased and disassembled for components reuse and materials recycling. The DTO system involves multiple uncertainties and variabilities due to different statuses of EOL products, so that it can be difficult to determine the number of takeback EOL products from suppliers to reuse, recycling or disposal facilities in order to satisfy multiple goals. To solve the multicriteria DTO problem, linear physical programming (LPP) is used by setting preference ranges for each criterion. LPP can remove weight allocation processes from a decision maker and express his/her preferences more flexibly with respect to each criterion. This study tries to achieve the higher aspiration levels of multiple goals simultaneously in the DTO system by using LPP. To demonstrate a design example, a numerical example is conducted.

Application of Fuzzy Logic in Selection of Remanufacturing Technology

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Abstract

Fuzzy approach is frequently used for selection of manufacturing technology. However, the application of the fuzzy tool for choosing the appropriate remanufacturing technology is seldom applied. This study applies fuzzy logic approach for the selection of technology in order to minimize vagueness in decision, thereby making results similar to experts' thinking. Through elicitation of experts' inputs, six cleaning technology were evaluated and ranked the appropriately using criteria of technology cost, operating cost, and disposal effect. Moreover, the technology selection

computed through experts' opinion using fuzzy logic inference system. The results show that when technical function of the technology is at low level of 20%, while the technology quality is as low as 15%, and the technology flexibility is rated low at 25%, then the technical adequacy of the assessed technology will be as low as 10%. The fuzzy approach shows that technology performance is largely impacted by criteria far beyond the technology itself, including purchasing cost, disposal cost, operating cost, and other support functions to compliment experience of experts. It is suggested that much as the management are doing appropriate decision for technology selection, fuzzy logic tool help to accommodate vagueness, ambiguity, and subjective views of experts. Notwithstanding the robustness of the approach, application of software to help selection of technology is more reliable and accurate, reduce time of decision, and can be accessed worldwide.

Decentralized Identification of Used Exchange Parts with a Mobile Application

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Abstract

Sustainable product development and use requires an extended life cycle of used and defective mechanical parts. Remanufacturing saves resources and helps the industry to utilize the product more efficiently. Reverse logistics is one of the most important challenges towards efficient remanufacturing. To improve this process, we propose an on site part identification at the workshops. A fast on site identification is essential for assisting repair shop personnel and saving time on searching for the right spare parts. Based on images taken by a mobile device our application provides various machine vision services, e.g. visual identification of used parts, already successfully tested in a sorting facility for remanufacturing parts. The mobile application provides a robust visual identification for different environments. We show that enhancing data for machine vision approaches with images from decentral sensors, i.e. mobile devices, leads to an improved identification accuracy.

Session 10: Sustainable Manufacturing Processes -
Manufacturing Processes, Tools and Equipment

Investigation of the Solubility of Liquid CO2 and Liquid Oil to Realize an Internal Single Channel Supply in Milling of Ti6Al4V

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Abstract

A sustainable approach to increase the productivity in milling of difficult-to-cut materials is the use of internal cryogenic cooling combined with minimum quantity lubrication (MQL). There are various systems available on the market to control the flow of the cryogenic and the MQL medium. These systems are usually based on a delivery of the media through two separate channels. Moreover, a single channel system, which uses the solubility of oil in supercritical CO2 is state of the art. Compared to a two channel system the geometry of the cooling lubrication channels is simplified, the tools are more stable and easier to manufacture. Furthermore, there is no negative interaction between the CO2 and MQL jets. Instead of supercritical CO2 (SCCO2), liquid CO2 (LCO2) is easier to handle and widely available. Therefore, this paper presents fundamental investigations of the solubility of liquid oil in LCO2. In addition, an innovative single channel system was designed, implemented and tested in milling process of Ti6Al4V.

Multi-criteria Decision-making for the Life Cycle of Sustainable High Pressure Die Casting Products

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Abstract

Although a significant body of literature has been devoted to metrics in manufacturing systems (including foundries) and their influence on decision-making, there is a scarcity of comprehensive and organic studies on performance indicators encompassing sustainability. A deterministic decision-making method will combine performance indicators as multiple criteria to identify the best material (among a number of alternatives) to manufacture a car transfer case with a High Pressure Die Casting process. Specific metrics will be considered according to different product life phases and process characteristics. Such metrics will be normalised by mass to extend the applicability of results to parts produced with the same process and similar design specifications but different mass. They will be categorised according to four main classes: cost, time, quality and

sustainability. The mentioned sustainability dimension of the analysis will influence the results to challenge well-established choices (with their relevant trends) seen in the automotive industry in the past decades.

A Thermal FEA Modeling of Multiple Machining Processes for Practical Machining Process Optimization

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Abstract

Surface integrity of machined surfaces has been considered critical as it relates to the sustainability performance of a machined product. A machined surface is often generated by multiple machining processes, the optimization for a sustainable machining process and machined product requires a consideration of the intermediate surfaces generated at each stage. This paper presents a rapid thermal finite element analysis (FEA) model established for cyclic surface removal processes to reveal the thermal mechanics. The model is considered a practical tool to implement a process optimization. The mechanical dynamics are simplified, and it focuses on thermal dynamics to enable fast computation and can be universally applied in different coolant applications including cryogenic machining. A roughing-finishing optimization is discussed based on the study regarding making rapid decisions making about parameter optimization for the multiple stages of machining.

Design of a Photovoltaic System with Ultracapacitor Energy Buffer

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Abstract

Global concerns over the damage caused to the environment by fossil fuels, as well as the instability of oil prices, has led to an increase interest in alternate electric power generation from renewable sources such as the sun, wind and geothermal energy. Solar energy is produced by solar panels which are made of materials having the capacity to create a flow of electric carriers when exposed to the solar irradiance. The efficiency of these panels depends on the sun light, and they cannot work at their maximum power point independently, hence, requiring Maximum Power Point Tracker (MPPT). This MPPT permits to compensate the changes in irradiance and temperature conditions and variations in load demands which cause power imbalances. As such, a photovoltaic system with supercapacitor energy buffer is designed using Psim software. The system consists of a photovoltaic array, a MPPT, a supercapacitor, and a charge controller which is to effectively balance and regulate power in the system.

Session 11: Sustainable Materials -
Composites and Plastics

Highly Rigid Assembled Composite Structures with Continuous Fiber-Reinforced Thermoplastics for Automotive Applications

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Abstract

Future technological and product developments will be measured by their improved resource and energy efficiency, as well as their competitiveness, while allowing effective climate and environmental protection. Manufacturing processes that are currently discrete for different groups of materials such as metals, plastics or textiles have to be merged to generate large-scale technologies for the sustainable production of high-performance structures for automotive applications. Fiber-reinforced plastics have been established in manufacturing components of high strength, stiffness and lightweight structures. Well-known examples are sandwich composites: an assembly of two continuous fiber-reinforced thermoplastic layers and an intermediate injection molded core structure. The vision is to make use of the savings potential of technology fusion and lightweight structures pursuant to the central idea of resource-efficient manufacturing technologies to produce multi-material components.

Increasing the Sustainability of Composite Manufacturing Processes by using Algorithm-based Optimization and Evaluation for Process Chain Design

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Abstract

Fiber-reinforced plastics (FRP) are predestined to be used in lightweight applications because of their superior weight-specific mechanical properties. Yet, many lightweight parts are still made of classic construction materials due to the resource and scrap intensive FRP production. The methods of Operations Research (OR) are a key enabler to overcome this problem and to facilitate a more sustainable use of production, planning and material resources. OR models are being used in other industries to reduce the costs for process planning by up to 45%. However, those methods have yet to be transferred and validated for planning of FRP production. The use of novel optimization models offers the potential to utilize resources more efficiently and reduce

development times by proper planning. This paper is about the development of a sustainable and resource-efficient methodology that implements OR models into the FRP planning process and offers the potential to reduce costs significantly.

Feasibility Study for Manufacturing CF/Epoxy – Thermoplastic Hybrid Structures in a Single Operation

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Abstract

CF/Epoxy sheet with injected thermoplastic is a hybrid structure that combines high mechanical properties of thermoset composite with the toughness and complex geometries of injected thermoplastic into a single component. To overcome the high cycle time and production cost associated with the manufacturing of such hybrids, the authors undertook a feasibility study for developing an integrated technology for the manufacturing of thermoset CF/Epoxy prepreg sheet and injected thermoplastic polypropylene. First, several demonstrator parts were manufactured to elucidate the effect of the process parameters on the process performance and the appearance of the final hybrid component. Then, to have a better understanding about the curing condition of prepreg sheet during this hybrid process, a set of numerical simulation was conducted to study the relationship between the initial preset machine parameters (i.e., holding time, injection speed rate,) on the temperature distribution and history of the prepreg sheet. The results show that the proposed technology is capable of manufacturing hybrid components in a single operation under different process and design conditions.

Energy- and Ecologically-oriented Selection of Plastic Materials

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Abstract

The plastics processing industry is one of the world's most energy-intensive industries. Therefore, the subject energy efficiency and the resulting ecological effects have a special significance. Energy efficiency measures concerning the machines, the supply structure and the process optimization. The influence of the processed plastic material on the energy demand hardly gets any attention. The selection of a type of plastic material depends on the product and the physical and chemical properties instead. The specific energy demand for processing the material and the ecological footprint however are not yet a decision criterion for use. The present paper shows by means of an extensive experimental study, that the specific energy demand of an injection molding

machine also depends on the processed material. For this purpose, a holistic experimental energy analysis is made and evaluated depending on the material used. The results show that the energy factor should be a decisive criterion for the future material selection process to achieve a more sustainable manufacturing.

Session 12: Crosscutting Topics in Sustainable Manufacturing -
Industry 4.0 and Sustainable Manufacturing

Identification and Structuring of Benefits and Expenses for Evaluating the Profitability of Investments in Digitalization within Production

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Abstract

Digitization opens up countless opportunities to improve a production. Potentials range from condition monitoring of individual machines to fully autonomously controlled production systems. Nevertheless, investments are usually required to exploit those potentials. Companies often need to connect machines, buy, update or expand IT systems or carry out projects regarding the digital twin across multiple departments. The implementation of such projects requires an integrated system analysis and thus know-how from the most diverse technical and scientific disciplines. An additional economic evaluation requires further economic know-how. This paper makes a contribution to identifying and structuring the potentials, benefits and costs of digitization. A scheme for the evaluation of investments in digitization is presented. It enables a structured analysis of restrictions, efforts and potentials of possible investments. The approach thus makes it possible to evaluate a potential investment within the setting of a workshop. This enables cross-departmental and cross-disciplinary understanding on the benefits and costs of an investment in the context of digitization. The method is presented on the basis of a project for introducing tablets in production at a switchgear manufacturer.

Development of an Intelligent Tool Condition Monitoring System to Identify Manufacturing Tradeoffs and Optimal Machining Conditions

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Abstract

Smart manufacturing has leveraged the evolution of a sensor-based and data-driven platform to improve manufacturing outcomes. As a result of increased use of sensors and networked machines in manufacturing operations, artificial intelligence techniques play a key role to derive meaningful value from big data infrastructure. These techniques can inform decision making and can enable the implementation of more sustainable practices in the manufacturing industry. In machining processes, a considerable amount of waste (scrap) is generated as a result of failure to monitor a tool condition. Therefore, an intelligent tool condition monitoring system is developed in this paper to identify sustainability-related manufacturing tradeoffs and a set of optimal machining conditions by monitoring the status of the machine tool. An evolutionary algorithm-based multi-objective optimization is used to find the optimal operating conditions, and the solutions are visualized using a Pareto optimal front.

Digitalization Technologies for Industrial Sustainability

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Abstract

Digital technologies are shown to perform a potential role in developing a resource efficient industrial base. The effective adoption of them can help to deliver reduced costs and improve the flexibility and sustainability of manufacturing systems. However, these positive benefits are far from guaranteed and the way in which digital technologies favor the transition towards sustainable manufacturing systems has not been analyzed in detail yet, so more conceptual and empirical investigations are required in this field. This paper develops a conceptual framework, which explains the potential significance of using digital technologies toward efficiency, resilience and sustainability. It also includes evidence from various case studies, which illustrate the core technologies which can potentiality contribute to a sustainable industrial future. The findings show some impressive results concerning the sustainable implications of the digitalization of manufacturing processes. If the predicted benefits can be achieved through digital technologies, they could massively impact on sustainability.

Session13: Sustainable Products -
Product Recovery, Reuse, Remanufacturing, and Recycling

Economics and Challenges of Li-Ion Battery Recycling from End-of-Life Vehicles

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Abstract

This study sheds the lights on current and future recycling methods for spent Li-ion batteries from retired vehicles. The demands of Li-ion batteries for automotive applications and power electronics are expected to increase significantly in the next 15-20 years. Recycling cathode materials from the end of life batteries is not only providing a sustainable source of materials, but also offers an economic alternative to some of the high value elements such as cobalt and nickel. Insights and directions for future R&D will be presented in this paper based on the results of the supply chain and techno-economic analyses made for end-of-life li-ion batteries.

Remanufacturing of Electric Vehicles: Challenges in Production Planning and Control

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Abstract

Due to the conceptual degrees of freedom in their product structure, electric vehicles offer high potential for remanufacturing-oriented product design. Remanufacturing as one fundamental element of a circular economy is characterized by specific challenges caused by uncertain information about the condition of the returning product. By means of a standardized survey within the remanufacturing industry the occurrence of uncertainties is confirmed and put into relation with challenges in the production planning and control (PPC) of remanufacturing operations. Furthermore, it is shown that strategies to deal with uncertainties currently used cause major inefficiencies that hinder economic remanufacturing of complex products like electric vehicles. Based on the result of the survey the requirements for a remanufacturing specific PPC system are derived from a practitioner's point of view.

Evaluation of Environmental Impact and Benefits for Remanufactured Construction Equipment Parts Using Life Cycle Assessment

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Abstract

Remanufacturing is an effective resource recycling approach that reproduces the used products to the same quality level of the new products through a systematic process. The remanufacturing of construction equipment reduces the negative impacts of the environment while ensuring sustainable productivity at low cost. In this study, LCA was implemented to analyze the environmental impacts including reduction of greenhouse gases and resources in remanufactured construction equipment parts. In addition, we analyzed the economic benefits of remanufacturing about the major parts of the construction equipment such as hydraulic cylinders, decelerators etc. In addition, life cycle impact assessment was assessed about human health and ecosystem destruction impact categories by applying an end-point methodology. The results of this study can be used as basic data for evaluating the environmental and economic efficiency of remanufactured construction equipment parts.

A Novel Approach for Developing a Flexible Automation System for Rewinding an Induction Motor Stator using Robotic Arm

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Abstract

Electric motor rewinding is a traditional restorative and regenerative process, which is lagging in adopting new and current market trend. Stator rewinding is a crucial task in electric machine manufacturing and is the most challenging operation so this has raised the need to automate the system. In this light, this paper aims to develop a concept for developing a flexible automation system for rewinding an induction motor stator using a robot arm. To achieve this, a bottom-up approach and model predictive control (MPC) has been utilized in the design due to manufacturers' specification disparities. The results reveal that the system can be trained successfully, to perform the remanufacturing process 6 times faster to the manual process and the system allows for data mining. Successful application of this approach will demonstrate the importance of using flexible automated systems for induction motor stator rewinding and it reduces time and winding steps.

Session 14: Sustainable Manufacturing Processes -
Manufacturing Processes, Tools and Equipment

Design for Eco-efficiency – A System of Indicators and their Application to the Case of Moulds for Injection Moulding

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Abstract

Eco-efficiency is a prominent as well as promising approach for fostering sustainability by assessing the environmental impact and value of companies´ activities simultaneously. A lot of indicators to assess both pillars – environmental and economic effects – are presented in different standards and guidelines. These indicators primarily refer to the "overall" evaluation of eco-efficiency at a company level. However, the concept of eco-efficiency seems to be fruitful for the sustainability-oriented analysis and design of single products and production processes as well. Since this task implies the need of other indicators, the paper presents a system of adequate technology-, product- and process-related indicators. A case study referring to moulds for injection moulding demonstrates the applicability and typical results of the suggested concept.

Assessment of Inflatable Core Assisted Paper Bottle Moulding Process

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Abstract

Eco-friendly products have gained importance in recent years. The paper bottle is a sustainable packaging solution for carbonated beverages. The moulding process is a two-stage process. At first, pulp is poured in the forming mould and fibers are formed in the desired shape. Wet bottle is then transferred to the drying mould to remove bound water. The drying process makes use of an inflatable core, which not only prevents the shrinkage of fibers but also helps in attaining good fiber compaction. Preliminary investigations reported uneven fiber compaction in changing curvatures and sharp corners. A cause of uneven thickness distribution in the geometry is uneven compaction pressure during core expansion. A FEM approach is developed to predict the occurrence of non-conformities in the bottle. Hyperelastic core material is modelled using Mooney-Rivlin material model from the elastic strain density function. The model can be used to optimize the core shape, thus developing a robust tooling solution.

The Evolution of Molds in Manufacturing: From Rigid to Flexible

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Abstract

Nowadays, dynamic products life cycles and increase in the number of product variants have led to reduction in demand per variant. This modern trend is in contrast with the high production volume of manufacturing processes such as injection molding, since they are commonly employed for mass production due to their long changeover time. Traditional rigid molds do not seem to be able to cope with the current industrial and market challenges. Flexible and reconfigurable molding processes, such as the discrete pin tooling systems and changeable molds, appear to be a promising choice for achieving manufacturing economic sustainability. They represent an effective way to save resources and reduce labor costs and setup times. This paper explores the evolution of molds used in manufacturing, from the old models to the current reconfigurable ones through a state-of-the-art analysis of academic research and solutions implemented by industry. Conclusions and insights are presented.

Effects of Cooling Lubricant on the Thermal Regime in the Working Space of Machine Tools

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Abstract

The use of cooling lubricant is indispensable for many milling and grinding machining tasks, primarily to achieve the best possible cooling and lubricating effect in the cutting zone and to reduce wear. In addition, tempered cooling lubricant carries out the function of heat removal from the working space. A reduction due to resource-efficient or ecological efforts has a direct impact on the temperature regime in the working space, which affects the thermal behavior of the frame structures and can cause machining inaccuracies. In this article, these effects of cooling lubricant on the thermal behavior of exemplary assemblies are modeled. Experimental investigations, based on temperatures and displacements, are compared with simulation-based calculations. The results include the description of the environmental conditions that must be taken into account when modeling frame structures and the influencing variables such as coolant temperature, supplied volume flow and extracted air volume.

Session 15: Sustainable Manufacturing Systems -
Manufacturing System Design

Zero-waste Production: Technology for the In-house Recycling of Technical Elastomers

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Abstract

When it comes to sustainability, the implementation of zero-waste production is an obvious goal to strive for. This is especially true for the field of technical elastomers where drop rates can be up to 80 %. Reusing production wastes for the original application saves primary resources and costs for disposal. Beside other hurdles the amount of wastes is often too small to be economically recycled with the existing technologies. Therefore, a highly economical recycling machine was developed. Through intensive redesign of known recycling technologies, their deficits have been resolved and a nearly 60 % reduction in energy consumption has been achieved. The so called "Reaktruder" was specially designed for small and medium enterprises and is already in use throughout Europe. By minimizing investment and wear costs, this technology can achieve a return on investment in about 1,500 hours. The development of this technology as well as practical examples of elastomer recycling will be given.

A Practical Approach to Reduce Energy Consumption in a Serial Production Environment by Shutting Down Subsystems of a Machine Tool

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Abstract

Energy efficiency in production is becoming increasingly important for the automotive industry, motivated by political regulations and competitiveness. Many theoretical approaches to achieve an efficient production via advanced control have only been tested in experimental environments. Important for the transfer into serial production is the proof that all requirements (e.g. quantity and quality) will be met. For ensuring production on demand, machine tools (MT) imitate the real production process to keep themselves at operating temperature.
All subsystems of a MT operate at full power in this state, disregarding its necessity. Shutting down these subsystems during non-productive periods is a promising approach for saving energy. This paper will present a method for shutting down components during non-productive periods, while ensuring the ability to produce on demand. Successful tests were already performed during live operation in a plant of a car manufacturer in Berlin, Germany.

Factors for Effective Implementation of Lean Manufacturing Practice in Selected Industries in Tanzania

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Abstract

Nowadays, in globalization industries are adopting new techniques and tools to produce goods for sustainability. However, manufacturing industries are facing challenges to minimize operations costs, market inconsistency, competition, and everlasting demands. Lean practice helps sustainability of the industries by doing more with less resources through elimination of non-value-added activities to maintain effectiveness and profitability. A study uses survey to identify factors for effective implementation of the lean manufacturing. Two industries producing plastics, metals, textiles, woods, biscuits, and bread products were selected for the study. The results revealed that manufacturing planning and control, new product development, process and equipment, concurrent engineering, workforce management, customer relationship, and supplier relationship are positive factors for the adoption of lean practice in Tanzania. Moreover, a lean model indicates that concurrent engineering has highest correlation to lean practice whereas new product development has the lowest significance. The new product development is not common because most industries lack innovation, limited technology, less desire of customers on changes of product features, dearth of research and development culture, lack of desire from top management, inadequate resources, and fear of failure for new product. It was advised that effective application of lean factors enables company to map risk of non-value-added activities and improve business value.

Session 16: Sustainable Manufacturing Processes -
Energy and Resource Efficiency

Techno-economic Analysis of Battery Storage Systems for Demand Responds Application in Manufacturing

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Abstract

Demand response mechanisms are considered a cost-effective strategy to increase the reliability of electricity grids and reduce the need for grid extension. The objective of the presented research is to conduct a techno-economic analysis for the use of battery storage systems in decentralized demand responds applications in manufacturing. In order to perform the analysis, different energy market scenarios were developed and a parameter study was conducted using simulation modelling. The results show that none of the 78 individual combination considered in the simulation experiment represent an economic viable investment scenario. However, small installed storage capacities perform superior to large installations in terms of net present value. The performed sensitivity analysis underlines that parameter sets for the battery systems, energy market models and control strategies require further research in order to improve the reliability of the simulation results. Aside of the techno-economic performance, the use of battery storage systems in decentralized demand responds applications need to be assessed in terms of its environmental impact.

Energetic Evaluation of Press Hardening Processes

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Abstract

The awareness and commitment to use carefully energy and other resources are increasing in view of climate change and the shortage of resources. Sustainable practice starts with sustainable production. The press hardening of sheet and tube metal components offers a range of optimization approaches. It becomes clear that a holistic view of the life cycle of components and products is essential. On the one hand, press hardening manufacturing process is significantly more energy demanding than conventional deep drawing process. On the other hand, they are also associated with significant energy and life cycle savings in the utilization phase of the manufactured product. The main focus of this work was on the visualization of energy consumption

as well as the development of innovative energy-efficient process chains for press hardening. Based on a technological analysis, the investigated process chains were energetically evaluated and approaches to improve the energy balance were deduced.

Modelling, Simulation and Optimization of the Comminution and Flotation Circuits of Platinum for Sustainable Mineral Processing

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Abstract

The quantum of minerals extracted from ore is critical for the success of mineral processing, hence the necessity to optimize the process flows in order to recover as much minerals as possible. The aim of this research was to identify bottlenecks and recovery-hampering factors within the comminution and flotation circuits of the concentrator plant at a platinum processing company in Zimbabwe. Modelling and simulation of the comminution circuit were carried using Arena and Limn simulation software to optimize the process flows for improved throughput, maximum mineral recovery and enhanced efficiency and productivity. Alternative configurations of the layout of equipment were experimented on and compared with the original setup. The recommended reconfiguration of the comminution circuit achieved increases of 2.97% in mineral recovery and 4 gram/ton in productivity resulting in a maximized output for the sustainable processing of ore.

Design Rules for Additive Manufacturing – Understanding the Fundamental Thermal Phenomena to Reduce Scrap

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Abstract

The goal of this work is to predict the effect of part geometry and process parameters on the direction and magnitude of heat flow – heat flux – in parts made using metal additive manufacturing (AM) processes. As a step towards this goal, the objective of this paper is to develop and apply the mathematical concept of heat diffusion over graphs to approximate the heat flux in metal AM parts as a function of their geometry. This objective is consequential to overcome the poor process consistency and part quality in AM. Currently, part build failure rates in metal AM often exceed 20%, the causal reason for this poor part yield in metal AM processes is ascribed to the nature of the heat flux in the part. For instance, constrained heat flux causes defects such as warping,

thermal stress-induced cracking, etc. Hence, to alleviate these challenges in metal AM processes, there is a need for computational thermal models to estimate the heat flux, and thereby guide part design and selection of process parameters. Compared to moving heat source finite element analysis techniques, the proposed graph theoretic approach facilitates layer-by-layer simulation of the heat flux within a few minutes on a desktop computer, instead of several hours on a supercomputer.

Session 17: Sustainable Manufacturing Processes -
Resource Utilization and Waste Reduction

Feasibility Study of the Materials Handling and Development of a Sustainable Conveying System in Plastics Recycling and Manufacture

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Abstract

The appropriate handling of materials in manufacturing is essential for the realization of reductions in direct and indirect costs. This research was carried out at a plastic manufacturing company in Zimbabwe where polymer pellets are used to produce plastic packaging. An in-depth work study was carried out at the plant followed by the feasibility, review and analysis of available and affordable conveying systems. A semi-automated pneumatic conveyor system comprising of a prime mover, feeder, and mixer was designed to replace the manual handling of materials. The analysis and eventual development of the optimal conveying system assisted the company in not only freeing up space for the uninterrupted movement of materials, but also improvements in safety and reduction in transportation and operational costs for the sustainable recycling and manufacture of plastic packaging. The research also contributed to the company's product quality and variability.

Value Addition to Plastic Solid Wastes: Informal Waste Collectors' Perspective

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Abstract

Plastic Solid Wastes (PSWs) recycling is an important component to sustainable manufacturing. In developing economies, the majority of the recovery and recycling is conducted by the Informal Waste Collectors (IWCs). An assessment is conducted to understand the ways in which the IWCs add value to the recovered PSWs prior trading to the plastic converting companies. A questionnaire survey is conducted with the IWCs and a total of 53 questionnaires are analysed. A number of value addition aspects are identified including; sorting, cleaning, classifying, washing and drying and grouping into commercial quantities. Buyers along the supply-chain are considered as an aspect of value addition. The identified value addition aspects are important and relevant to upcoming and existing plastic convertors in terms of driving sustainable manufacturing and value creation for a circular economy.

A Data Architecture to Aid Life Cycle Assessment in Closed-loop Reusable Plastic Container Networks

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Abstract

Returnable container networks have caught the eye of those companies that aim to reduce waste generation and environmental impact. The literature already includes studies on the environmental impact (i.e. Life Cycle Assessment, LCA) of these networks. However, the major part is based on secondary data, since the collection of primary data results complex and time-intensive. This paper proposes an object-relational database dedicated to the storage of data from closed-loop reusable plastic crates (RPC) networks for fruits and vegetables. The goal is supporting scholars and managers during the LCA through a user-friendly data architecture, while suggesting structured guidelines for the primary data collection. Each node of the RPC network is characterized by a similar set of entity types, such as machines, that allows to process the RPCs with respect to specific cycles. Each entity, process and cycle is therefore reflected in the database by objects that are connected with relations.

Session 18: Sustainable Manufacturing Processes -
Energy and Resource Efficiency

A Practical Framework for the Optimization of Production Management Processes

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Abstract

Production optimization can be done on different levels, ranging from improving individual machines, over organizational aspects like Kanban, to optimizing the overarching production planning. The last approach may inherit the greatest potential. Still, it is also the most challenging since it requires a holistic systems engineering approach. One of the main challenges is the lack of an overall optimum. Wiendahl represents the conflict of objectives in the polylemma of production.
The paper presents a practical framework for the optimization of production management processes. We derived it from a variety of corresponding projects. It describes how the conflict of objectives can be analysed systematically and a reasonable operational status can be derived. Questions of medium and short-term production planning are addressed. This includes the definition of the analysis objective, the analysis of the initial state and the optimization. The phases are each described with the help of examples.

Framework for Energy Efficiency Optimization of Industrial Systems based on the Control Layer Model

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Abstract

In the context of sustainable manufacturing, the energy efficient operation of industrial systems is of major interest. This paper presents a modular framework for practical research about energy efficiency optimization of complex technical systems. Whereas many approaches focus on stand-alone machines or processes, this approach is concerned with energy-related coupling of several entities. Using a method for energy-related key performance indicators, the overall efficiency is deduced from all subsystems. A given topology is modeled in an XML-based format, inspired by AutomationML. The framework gives the opportunity to analyze and compare optimization algorithms. First experiments with two optimization algorithms were applied to a simulated cooling system.

Improving the Energy Efficiency of Industrial Drying Processes: A Computational Fluid Dynamics Approach

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Abstract

In order to reach the United Nation's Sustainable Development Goals, increasing the efficiency of industrial processes is one of the core components. As value adding processes in manufacturing determine the quality of the product significantly and are more difficult to adapt, non-value adding processes are primarily in the focus of efficiency measures. Especially when considering the energy balance of a component over its entire lifecycle, processes such as drying play a decisive role. This paper discusses an approach to increase energy efficiency during the drying process of metal parts in electroplating processes by improving the air guidance inside industrial drying chambers. In addition to a numerically investigation using a computational fluid dynamics approach, in-situ measurements of the energy consumption of a dryer were carried out. In order to measure the positive effects of the improved flow, a prototype of such a dryer will be developed and energetically measured next step.

Methodology for the Early Analysis and Evaluation of the Resource Efficiency of Process Chains for Manufacturing Hybrid Structures

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Abstract

To ensure a successful development of resource-efficient and sustainable technologies, products, and production processes, it is essential to support R&D activities in early design stages. Thus, amongst others an appropriate assessment should be accomplished, which captures the high complexity and interdependencies of process chains, considers the technological feasibility, the energetic and economic benefit as well as the robustness as facets of resource efficiency, and hence, serves as a basis for deriving impulses for R&D activities. A promising evaluation methodology for such assessments is the **M**ultidimensional **E**valuation **M**ethod for **P**rocess Chains of **H**ybr**I**d **S**tructures (MEMPHIS). In this paper, MEMPHIS is outlined and illustrated for an

innovative process chain for producing hybrid laminates with sensor functionality. As a result, the paper will contribute to the further development of the methodology, show its applicability, and provide insights into the innovative technology.

Session 19: Sustainable Manufacturing Systems -
Production Planning, Scheduling and Control

Mathematical Model for Proactive Resequencing of Mixed Model Assembly Lines

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Abstract

Mixed model assembly lines are state of the art for automotive mass production. In the context of mass customization and individualization the car sequencing recently became more and more challenging due to varying assembly tasks and processing times. Classical principles such as the vehicle pearl chain are thus reaching their limits. Therefore, planned changes in the vehicle sequence during final assembly, Proactive Resequencing, was proposed to optimize utilization segment by segment. The concept leads to a long-term buffer planning problem on a strategic level as well as to an adapted vehicle sequencing problem with enhanced flexibility on an operative level. This paper introduces a mathematical model for the combined buffer planning and order sequencing problem for automotive assembly lines. It also outlines a solution approach for the mentioned production planning challenges separated by their timing preferences.

User-Centric Process Management System for Digital Transformation of Production

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Abstract

Digital transformation is one of the most influential developments of our time, leading to profound changes in production work. The creation of sustainable structures in existing or expanding production environments without losing sight of people requires Industry 4.0 solutions that are future-proof, cost-effective and can be used as needed. In order to meet these challenges, a high level of user acceptance has to be achieved and the process of digital transformation has to be designed, taking the experience of the employees into account. This article presents an approach for the digitization of the foreman experience by using enterprise models in a user-centric process management system. A baseline concept for digital transformation is applied to evaluate the solution's contribution to industry 4.0 capability in small and medium sized enterprises.

Inventory Management and Performance of SMEs in the Manufacturing Sector of Harare

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Abstract

The study assessed the inventory management (IM) strategies that are used by SME's in the manufacturing sector of Harare, Zimbabwe. The study comprised of the population from Gleview complex, Siya So Mbare, Kuwadzana, Gazaland and Magaba industrial sites. Respondents were selected from the each of the companies which the researchers selected purposively. The study used qualitative research design which was descriptive in nature. The study also used purposive sampling technique. A sample used a sample size of 244 respondents. Data was collected from the questionnaires which were completed and received back. The research established that most SME's use the Just-In-Time method of inventory management and do not have knowledge on the other computerized systems and methods. Since companies use JIT method, SME's face challenges in the supply chain as they always have to make sure they have constant communication with their suppliers and also to reduce the time in which they receive materials. However due to lack of computerized communication, they have to make orders when they are needed which would make delays to the customer. Due to the finding the researchers concluded and also made request for further studies on specific areas which needed more time and clarity.

Web-based Process Planning System Concept Selection using Weighted Decision Matrix and Analytical Hierarchy Process: A Case Study of Sheet Metal Bending Operations

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Abstract

The demand for sheet metal bending products has pushed the sheet metal industry to adopt new process planning approaches that can transform the existing systems in order to improve efficiency and reduce costs during product design and manufacture. Sheet metal industries are still using traditional system planning methods, which has limited capacity to respond to rapid changes in market requirements. In light of this, this paper proposes a suitable web-based process planning system that can be used to effectively bend varieties of sheet metal products using various bending press machines. Three (3) web-based process planning system concepts were formulated in this study and evaluated using various criteria. The result of the Weighted Decision Matrix (WDM) and the Analytical Hierarchy Process (AHP) analyses revealed that web-based process planning system concept Y with a cumulative assessment score of 1.90 and a priority assessment score of 0.637 is the suitable web-based process planning system that could be used to effectively bend varieties of sheet metals. This evaluation approach serves as a useful information for system designers in other manufacturing sectors, to select suitable systems capable of effectively carrying out their operations.

Session 20: Crosscutting Topics in Sustainable Manufacturing - Education and Workforce Development

Augmented Learning for Industrial and Higher Education

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Abstract

An efficient learning environment is required to cope with today's increasing innovation speed. Companies and universities need methods and tools to transfer the new knowledge in a fast way to employees and students. The cognitive load during learning situations has to be reduced to enable a better focus on the learning content rather than on the learning method. Current learning environments are mostly not capable to directly combine physical learning tools with digital content, so that the cognitive load of the learner is reduced. Augmented Reality offers the opportunity to show learning content directly on physical objects and to interact with it. Within this paper two approaches on how to use augmented reality for teaching purposes are shown. One purpose is for the special machinery assembly of turbomachinery and the other is for the cocoa liquor production.

Sustainable Engineering Master Module – Insights from three Cohorts of European Engineering Team

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Abstract

Mobility and transnational migration are current social developments among the population of the European Union. These developments in both society-at-large and companies, linked to the challenges of sustainability, lead to new requirements for working in the European Union. Teaching and learning in higher education needs to adapt to these requirements. As a result, new and innovative teaching and learning practices in higher education should provide competencies for transnational teamwork in the curriculum of tomorrow's engineers in order to ensure their competitiveness in the job market and advantage in their future careers. A transnational project-oriented teaching and learning framework, which provides the future key competencies for young engineers was implemented in the course European Engineering Team (EET). Engineering students from four countries participated in a new project-based course that focused on the development of innovative and sustainable products and opportunities. The goal of this paper is to present results and lessons learnt from three cohorts of EET.

Circular Economy in Integrated Product and Production Development Education

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Abstract

Global operations are accelerating the diffusion of technology and the pace of innovation. The increased demand for ICT and problem-solving skills requires new methods and tools to support continuous learning paradigm. The emergence of circular economy (CE) paradigm is demanding the companies to change and take broader role in the value chain. Within these new valuechains, the manufacturer plays central role re-designing products for multiple uses and proposing new consumption patterns to customers through innovative services covering the current and future life-cycles of the product. This new level of complexity and interconnection puts a pressure to the education system, which traditionally is highly focused on its own priority areas. The paper will present an approach to speed uptake of CE business potential by introducing an education module created in collaboration with industry and academia to support the creation of new talents in the field of manufacturing industry.

An Online Education Model for Next Generation Sustainable Manufacturing Workforce Development

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Abstract

Successfully implementing sustainable manufacturing practices in industry for sustainable value creation requires a workforce that possesses the necessary knowledge, skills and abilities (KSA). In addition to educating and training future engineers/managers to instill the sustainable manufacturing KSAs, continuing education to ensure that those in the incumbent workforce are (re)educated and (re)trained to enable innovation and technology development for sustainable manufacturing is also essential. In this paper, we present a novel approach for online graduate engineering education, that has been tested and validated through a master's degree in manufacturing engineering, as a model for next generation sustainable manufacturing workforce development. The features of the current online degree program will be discussed and compared with conventional face-to-face and classroom-based programs to elaborate the benefits of the online education modality. Finally, a methodology to extend the existing degree to develop an online master's in sustainable manufacturing will be briefly discussed.

Session 21: Sustainable Manufacturing Systems - Sustainable Supply Chains

Analysis on Sustainable Supply Chain for Circular Economy

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Abstract

In recent years, organizations have started focusing on sustainable and green practices to address environmental, social, and economic concerns that form as an approach, which strives for the growth of an organization to encourage adapting the circular economy. The objective of circular economy is to extract the advantage of materials, energy, wastes of an industry. The circular economy associates the supply and demand of supply chain industries to improve resource efficiency. The research paper has analyzed a case example in a supply chain organization to meet industry 4.0 requirements and enable circular economy. An analysis on supply chain industry has been conducted with the focus on 6Rs such as Recover, Reuse, Remanufacture, Recycle, Redesign, Reduce. The article highlights the opportunities available in the transformation from linear economy to circular economy, which improves social, economic and environmental drivers of the organization. In addition, it also discusses the opportunities available in industry 4.0 for circular economy.

The Use of Data Envelopment Analysis in Evaluating Pareto Optimal Solutions of the Sustainable Supply Chain Models

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Abstract

Background of sustainability is summed up by three words: Planet, People, and Profit. The 3Ps of sustainability requires multi-objective research. This study analyzes the evaluation process of multi-objective optimization. Since it is highly critical for decision makers to understand the results of multi-objective models, Data Envelopment Analysis (DEA) approach is used to put Pareto-optimal results of the model in an order and to analyze it. A case study of a reverse supply chain model with four objectives namely economic, social, environmental and, legal is taken into consideration. Results of the DEA evaluation showed that the method can be effectively used in interpreting the results both in academics and decision makers.

Challenges Faced by the Mining Sector in Implementing Sustainable Supply Chain Management in Zimbabwe

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Abstract

Sustainable supply chain management (SSCM) is the incorporation of ecological concerns into the inter-organisational exercises of supply chain management. The implementation of SSCM in the mining sector has been a slow process. The study was conducted to determine the challenges facing effective implementation of sustainable supply chain management within mining sector in Zimbabwe. The researchers employed a case study of mining sector, where descriptive data research method was utilized with a target population comprising 1000 companies and a sample of 91 organizations was obtained, using Slovin's equation. The researchers adopted the convenience sampling technique which involved the choice of subjects who were well equipped with relevant information to the researchers focus. A convenient sample size of 40 mining companies in Zimbabwe was selected based on of researchers' easy accessibility to them. The findings revealed that, presently there is absence of structural and organisational change to support implementation of sustainable supply chain management. The study recommends that the organisations and different stakeholders should ensure that there is structural and organisational change to support, improvement of legal and regulatory framework on environment, reduction of cost connected with green products and distribution of resources vital for effective implementation of sustainable supply chain management.

Evolution of Supply Chain Management: A Sustainability Focused Review

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Abstract

The purpose of this paper is to historically investigate the past and current developments of supply chain management (SCM) to identify key possibilities and future trends. Through literature review and observing the developments of SCM, the paper first reveals early concepts of SCM in manufacturing and business operations. Then, it discusses the system integration and collaboration mechanisms, presenting the dominant focus in current research and applications. Finally, recent technological advances that are likely to impact SCM along with pressures for environmental sustainability are recognized as potential research directions. Contributions to sustainability along the SCM evolution is also noted. The paper is original in the way in which it draws on an entire study to summarize the developments of SCM over time, which will be significant for theorists and practitioners to meet the future challenges.

Session 22: Sustainable Processes -
Manufacturing Processes, Tools and Equipment

Experimental Methods to Study Environmental Sustainability of Silicon-based Lithium Ion Battery Manufacturing

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Abstract

Next-generation lithium ion batteries (LIBs) are under rapid development using various nano-structured materials. Among them, silicon nanowires (SiNWs) and silicon nanotubes (SiNTs) are two promising anode materials due to their high specific capacities. However, fabrication processes of SiNWs and SiNTs involve a large amount of toxic chemicals and generate significant potential impacts on the environment. In this study, both in-situ and ex-situ measurements were proposed for investigating the process emissions, including gas, aerosol nanoparticle, and aqueous nanoparticle emissions, from chemical etching processes for producing SiNWs and SiNTs for use as anode materials for LIBs. The feasibilities of the measurements were verified by the preliminary results of the emissions from the SiNTs synthesis process. This study provides insight into experimental measurements of and supports the gathering of process data on emissions from synthesis processes for SiNWs and SiNTs as anode materials for LIBs, which can be useful for future assessment of the sustainability performance of silicon-based LIB technology.

Emerging Manufacturing Technologies for Fuel Cells and Electrolyzers

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Abstract

Fuel cells have emerged as viable solutions in areas such as stationary and backup power systems, material handling equipment (MHE), and fuel cell electric vehicles (FCEV). Persistent challenges for fuel cells and electrolyzers include high initial cost and the availability of hydrogen infrastructure to support FCEV and MHE fleets. Cost of fuel cells are still high compared to other power generation systems such as diesel and natural gas generators. This, however, can be linked to two facts: first is low production volumes generally and second is emerging manufacturing technologies currently in R&D that need to be scaled up to factory production volumes. This study investigates current manufacturing processes used in production of fuel cells (e.g., spray coating and manual assembly) and emerging manufacturing technologies (e.g., roll-to-roll catalyst coating) to investigate key cost drivers and potential cost reductions in manufacturing of fuel cells and electrolyzers. In particular, we focus on how cost reductions for advance manufacturing technologies may be more significant at scale than existing technologies.

Evaluating the Usability of Bio Coal from Sugar Cane Bagasse as a Solid Fuel

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Abstract

The potential to produce a high calorific value bio coal from sugarcane bagasse for alternative use to coal which is used for energy generation in the sugar industry was investigated. Bagasse being a lignocellulose waste material generated from sugar processing has energy potential to produce eco-friendly bio coal. The bagasse was first dried to reduce the moisture content and then was subjected to carbonization at 250-400 ◦C for conversion of the bagasse to bio char. Bio char yield observed during torrefaction was 70%. The bio char was then ground to 300 microns particle size sand then compacted to bio coal at 2-8MPa using molasses in the ratio 70: 30. The bio coal had a calorific value of 28.2 MJ/kg, moisture content of 6.3%, fixed carbon of 74.6% and ash content of 1.4%. The properties of the bio coal makes it makes it usable as an alternative to coal and can be reintegrated back in the sugar processing industry as a substitute to coal.

Perfect Repair Constraints in Manufacturing Firms – A Case Study

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Abstract

Physical assets reliability is always called to question whenever manufacturing throughput is constrained by equipment availability. The equipment unavailability is generally attributed to functional failure, and one of the ensuing remedial actions to get the machine back to working condition is to institute repairs on the equipment. The degree of repair is scrutinized to give credence to the status of manufacturing assets on the ground, and the measure is focused on how perfect the repair was. A case study was carried out on a manufacturing firm to explore the different types of repairs that were being carried out on the manufacturing physical assets, aimed at understanding the factors that led to the choice of the repair type(s). The main focus of the study was on the application of perfect repair on physical assets, and the factors that prevented the organization from sticking to commitments of instituting perfect repairs always. The repercussions of not being able to institute perfect repairs were also assessed, and the understanding of optional remedies to ease the risk of further functional failures was also considered

Session 23: Sustainable Manufacturing Processes -
Process Modeling and Improvement

Influence of Constitutive Models on Finite Element Simulation of Chip Formation in Orthogonal Cutting of Ti-6Al-4V Alloy

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Abstract

Cutting simulation technology is widely used to predict the micro-scale and instantaneous information in cutting and can be used to reduce the manufacturing costs in industry. Material constitutive models characterize the deformation behaviors involved in cutting and are the key factors affecting the simulation accuracy. In this work, different plastic constitutive models, JC model, JCM model and KHL models were used to simulate the segmented chip formation in Ti-6Al-4V alloy orthogonal cutting. Meanwhile, the JC damage initiation as well as energy-density based damage evolution criteria were applied in cutting simulation. A VUMAT subroutine was developed to characterize the stable plastic and damage constitutive model. The simulated chip morphology using different constitutive models was compared with the experimental results. The plastic models and the ductile failure model can characterize the flow softening behavior during segmented chip formation. The influence of plastic model on the principle cutting force and the segmented chip morphology at different cutting conditions was discussed.

Fuzzy Multi Criteria Approach for Sustainable Maintenance Evaluation in Rubber Industry

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Abstract

This paper proposes a fuzzy multi criteria approach for evaluating sustainable maintenance in rubber industry. A literature study is conducted to identify the key performance indicators (KPIs) and then validated by academics and industry experts. As a result, three factors of economic, social, and environmental dividing into a total of thirteen indicators are proposed as the KPIs for sustainable maintenance evaluation in rubber industry. Next, the Interpretive Structural Modeling (ISM) method is applied to determine the interrelationships of KPIs. The results identified four indicators of environmental factor as the most influencing KPIs, while six indicators of economic factor suggested as the most influenced KPIs. Finally, the Fuzzy Analytic Network Process (FANP) method is used to determine the importance weight of KPIs. The lighting and ventilation is regarded as the most important KPIs, followed by working environment, energy consumption, and emission. The proposed evaluation model is expected to assist the rubber industry in improving their sustainable maintenance performance.

Process Sustainability Evaluation for Manufacturing of a Component with the 6R Application

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Abstract

Sustainability in manufacturing can be evaluated at product, process and system levels. The 6R methodology for sustainability enhancement in manufacturing processes includes: reduced use of materials, energy, water and other resources; reusing of products/components; recovery and recycling of materials/components; remanufacturing of products; and redesigning of products to utilize recovered materials/resources. Although manufacturing processes can be evaluated by their productivity, quality and cost, process sustainability assessment makes it a complete evaluation. This paper presents a 6R-based evaluation method for sustainable manufacturing in terms of specific metrics within six major metrics clusters: environmental impact, energy consumption, waste management, cost, resource utilization and society/personnel health/operational safety. Manufacturing processes such as casting, welding, turning, milling, drilling, grinding, etc., can be evaluated using this methodology. A case study for machining processes is presented as an example based on the proposed metrics.

Signal-based non-Intrusive Load Decomposition

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Abstract

Driven by both regulatory and monetary interests the development of energy monitoring systems has been accelerated in recent years. Thus, a large amount of data is collected and stored in huge databases. This is a decisive step towards sustainable production systems since you can't improve what you don't know. This paper aims to use the datasets currently available and to combine databases to gather additional information on production systems, in particular energy flows. Therefore, an algorithm has been developed that combines energy consumption data from production lines with production information to estimate the consumption of connected subsystems. This paper analyzes the algorithm with case studies from companies with their specific databases and will show a deviation of less than 5 % of accumulated energy. Hence, the algorithm is able to create a more detailed analysis of production systems without additional sensor installations by combining existing databases.

Session 24: Crosscutting Topics in Sustainable Manufacturing - Challenges and Strategies in Emerging Countries

Environmental and Social Sustainability of Sri Lankan Tea Industry in the Wake of Global Market Challenges

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Abstract

The tea industry, with more than 150 years of history, is one of the main export earners of Sri Lanka. This industry currently faces severe threats to sustaining due to economic, social and environmental problems such as lack of productivity, yield drop, climate change impacts, labour shortage and internal migration of workforce etc. Therefore, this study focuses on the environmental and social impacts of this industry and to propose sustainable value creation model to face global market challenges and regulations. The environmental aspects of the tea processing were analysed using LCA technique, while social aspects were evaluated as social LCA. The fieldwork being carried out in one of the leading tea plantation companies in Sri Lanka. It is evident that there are multiple areas, inside and outside of the process, which needs improvement. However, the planation company considered in this study maintain social and environmental standards at a higher level when compared to industrial average situation.

Industrial Sustainability in a Challenged Economy: The Zimbabwe Steel Industry

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Abstract

The economy of Zimbabwe has deteriorated over the years with hyperinflation. In the years 2006 to 2008 the conditions worsened and in 2009 a multicurrency system including the US dollar was introduced, however investment in the industry did not strengthen and a number of challenges are still faced by the industry. A main feature of the Industry in Zimbabwe had been the steel and steel related manufacturing industry which was key for both domestic and foreign markets. The motivation for this study was to investigate and propose strategies for enhancing sustainability of steel making companies in Zimbabwe. The aim of this research was to undertake a requirements analysis from the steel companies and identify the main challenges from the point of view of steel production. From these challenges the paper aimed to help co-define some of the possible solutions the companies could consider. Sharing the findings could help companies pick up best practice and inform policy makers in developing new frameworks for improving industrial sustainability.

Innovation Catalysts for Industrial Waste Challenges: Sri Lankan and Thai Cases

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Abstract

We explore the specific challenges that Asian developing countries experience with their industrial waste from manufacturing. We collected empirical data in Sri Lanka and Thailand through four workshops, 16 interviews and in-situ observations within Sri Lankan garment manufacturers, academics and NGOs; and Thai SMEs of wood, metal, plastic, automobile part and glass. Whereas garment manufacturing is the single biggest export industry in Sri Lanka, the Thai economy operates with wider industry sectors. The synthesis of the identified challenges is fed into a set of innovation catalysts along with sustainability consideration points that will support future innovation concept generation. The findings would allow a better understanding of current waste problems and navigate the starting point to tackle the waste problems for academia and industry in both countries. The study lays the foundation for further investigation into sustainable value creation through creative waste innovations.

Road to Sustainable Manufacturing: Why Households Are Not Participating in Recycling Programs in Ndola, Zambia?

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Abstract

A number of factors are important and key to achieving sustainable manufacturing in the plastic industry. Recycling has received considerable attention as a key to sustainability. It contributes to resource utilization and waste management. To achieve sustainability, a number of stakeholders are involved and households are a key aspect. A survey of 445 households is conducted to establish factors that prevent households from participating in plastic recovery and recycling programs. The results indicate relevant factors for consideration by the plastic industries and policy makers when designing recycling and recovery programs.

Session 25: Crosscutting Topics in Sustainable Manufacturing - Strategies and Performance Assessment

Metrics for Identifying the Most Suitable Strategy for Distributed Localised Food Manufacturing

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Abstract

The globalisation of manufacturing systems has generated many economic benefits, but in some areas such as the food sector, it has also increased resource requirements to manufacture, preserve and transport raw ingredients as well as finished products. 'Distributed Localised Manufacturing' (DLM) has been identified as a potential solution for the food sector to adopt a more sustainable approach based on a make-to-order manufacturing strategy. This has the potential to minimise food waste, optimise resource usage, and support product customisation. However, DLM performance analysis at product, process and system levels is vital to ensure its long-term ecological and economic viability. This paper highlights four possible models for implementation of DLM in the food sector, defines nine key metrics to aid with selection of the most suitable DLM model for a specific food product family, and explores metrics future applications to support long-term sustainability of food manufacturing.

Strategic Local Manufacturing Supplier Development Roadmap as a Decision Support Tool

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Abstract

Local manufacturing suppliers are critical to a country's economy and to ensure sustainability. In order to address all key areas for developing a local manufacturing supplier (LMS) from the informal- to the formal economy a strategic approach is required. A systematic literature study was conducted to establish the theoretical foundation. The conceptual roadmap was validated using case studies and the key elements, sequence of development phases, types of development projects and the role each stakeholder plays along the development of local suppliers were evaluated. This holistic roadmap for developing a LMS, as a strategic decision support tool can assist the end user to make informed decisions of the current maturity level and to determine the most appropriate LMS to develop. The roadmap further establishes a clear prioritised action plan relative to its maturity phase.

Data-driven Sustainability in Manufacturing: Selected Examples

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Abstract

Sustainability in manufacturing is an imperative of growing importance to preserve our world's resources. This paper emphasizes the notion that data collection, data analysis and data-driven control strategies in manufacturing are key to achieve more sustainable manufacturing. This is discussed with selected examples from quality assurance, machine tool design, and worker expertise. Quality assurance is the enabler of high quality products, low scrap rates, and fault-resistant manufacturing practices. Machine tools are large consumers of energy in manufacturing and need to be designed with resource-efficiency in mind. The worker is another integral component of sustainable manufacturing, enabling highly efficient operations through his or her expertise, which can be demonstrated with the example of manual grinding. The selected examples exemplify how comprehensive data on different temporal and spatial levels enables data-driven sustainability in manufacturing, which helps achieving a truly circular world.

Sustainability Reporting in German Manufacturing SMEs

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Abstract

This paper investigates how small and medium-sized enterprises from the German manufacturing sector address sustainability issues through the implementation of sustainability reporting. For this purpose, 14 sustainability reports were analyzed with regard to the extent that they apply the framework provided by the Global Reporting Initiative (GRI), as well as the differences between companies that apply the GRI framework and companies that do not. In addition, indicators and related units that are used to report sustainability are investigated. The findings of this contribution show that there is a general lack of consistency among the considered sustainability reports, which demands for further harmonization of sustainability reporting in order to ensure comparability of sustainability performance across different organizations.

Session 26: Sustainable Manufacturing Processes - Cutting Technologies

Ecological and Functional Optimization of the Pretreatment Process for Plasma-based Coatings of Cutting Tools

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Abstract

Increasing demands in machining of high-tech materials and dry machining lead to higher thermal and mechanical loads on cutting tools. In response to these challenges, enhanced coating solutions are applied to increase performance and life of cutting tools. However, during the production process the cemented carbide substrates are contaminated with grinding oils and residues of organic material. For the subsequent physical vapor deposition (PVD) coating process an intensive and high-quality cleaning process is necessary. In this contribution, plasma electrolytic polishing (PEP) is used as a novel alternative to conventional ecologically harmful cleaning baths. Apart from the ecological advantage, the surface of the substrate can be optimized with regard to the coating adhesion. To examine the performance of the different cleaning processes, machining tests were performed at the IWF to evaluate the layer adhesion and tool life of the tools.

Constant Surface Roughness over Tool-Lifetime due to Online Process Monitoring and Cutting Parameter Adaption in Turning of Gear Steels

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Abstract

Due to high process forces and temperatures in turning operations, cutting inserts are subjected to rapid tool wear. Tool wear like abrasion at the flank face has direct impact on process forces, workpiece geometry and resulting surface roughness. Since tools are used until tool life criterion is reached, surface quality can vary widely over the workpiece even when constant cutting parameters are utilized. At the IWF a measurement system based on laser triangulation has been developed which enables the online measurement of surface roughness on the workpiece during turning process. A variety of tests has been undertaken to evaluate the measurement system. Effects on surface roughness due to advancing cutting edge rounding or tool breakage were detected with high accuracy. Using the online surface roughness measurements, a closed-loop

controller was realized in order to adapt the feed to retain constant surface roughness on the workpiece even when tool wear is progressing. An optimized process with constant cutting parameters was benchmarked to the developed process with adaptive cutting parameters. Furthermore, it was shown that parameter adaption has the potential to lead to more stable and efficient processes and increases the tool-lifetime drastically.

Comparison of Abrasive Water Jet Technologies in Terms of Performance and Kerf Geometry Accuracy for Cutting Ceramics

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Abstract

Hard machining of brittle materials such as ceramics is a process-oriented challenge. For the machining of such materials, abrasive water jet cutting is an appropriate alternative to the commonly used diamond grinding and laser cutting processes. In abrasive water jet machining the injection technology is currently used almost exclusively. Due to the realization of the suspension jet technology a higher cutting performance can be achieved. In this article, the known injection technology and the suspension technology are compared. To do so, the influences on the quality were examined for trimming technical ceramics. The investigation illustrates that suspension technology trims with a higher accuracy than injection technology in matters of kerf geometry but with a lower material removal rate.

Session 27: Sustainable Manufacturing Processes -
Energy and Resource Efficiency

On How the Selection of Materials Affects Sustainability

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Abstract

The selection of the materials for the production of aerospace engine products is directly related with their performance in tough working conditions. However, the extraction of the materials require high amount of energy, use water and emit CO_2, which can be directly related with environmental sustainability. The abundance of the materials, their sourcing and geographical location, can be further related to economical and social sustainability. Manufacturing companies look for different materials and cutting data that will optimize material removal rate, cutting tool utilization, required cutting time, costs, energy used, CO_2 footprint, coolants, etc. Here is presented a simple methodology to calculate the sustainability impact of the selection of materials. The study compares a simplified theoretical work piece that is geometrically complex and made of difficult to machine material, e.g. Ti-6Al-4V and MP159. The study shows how to select the optimal material, not only in terms of costs, but also in terms of environmental, societal and economical sustainability.

Energy Demand Reduction of Aluminum Alloys Recycling through Friction Stir Extrusion Processes Implementation

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Abstract

Aluminum alloys are characterized by high-energy demands for primary production. Recycling is a well-documented strategy to lower the environmental impact of light alloys production. Despite that, conventional recycling processes are still energy-intensive with a low energy efficiency. Also, permanent material losses occur during remelting because of oxidation. Recently, several solid-state recycling approaches have been analyzed; in fact, by avoiding the remelting step both energy and material can be saved and, therefore, the embodied energy of secondary production can be substantially reduced. In this paper, the solid-state approach Friction Stir Extrusion (FSE) is analyzed for aluminum alloys recycling, the primary energy demand of such recycling strategy is quantified. Comparative analyses with both conventional and direct extrusion-based processes are developed.

Material and Process Selection Sustainability Aspects

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Abstract

This work discusses specific roles of material and process selection on the overall sustainability of manufacturing practices; with focused treatment of the automotive industry. Usefully, the paper will focus on the development of material selection indices that describe the material different effects on resources mainly; resource depletion, water pollution, recyclability; also the material forcings on the product sustainability are analyzed from the life-cycle assessment and durability aspects. In regard to the process-selection, the text will present a case study specific to panel forming techniques, by proposing a sheet-metal origami folding approach. Origami folding of sheet-metal will first be motivated and justified through its potential of energy savings and process consolidation for automotive production lines; followed by an actual case study implementation, which introduce the origami mathematics of design, and the folding features concept.

Session 28: Sustainable Manufacturing Systems -
EoL Strategies and Performance Assessment

Economic and Environmental Evaluation of Aluminium Recycling based on a Belgian Case Study

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Abstract

The increasing demand for aluminium (Al) has led to the significant growth of secondary Al production. Although Al is one of the most recycled metal streams, the presence of impurities, such as iron, silicon and copper, has limited the environmental and economic benefits of recycling Al. These competing interests have led to the choice of recycling options that is suboptimal. This paper evaluates the economic and environmental effects of recycling different Al scrap qualities based on data collected from a Belgian recycling facility. Observations from the case study show that the profit-driven recycling market has led to a recycling system that does not produce the best environmental impact outcome. Maximising the environmental benefits of material recycling is often secondary to profit generation from the recyclers' perspective. There is a need for stricter measures, such as environmental tax on primary Al production, to address the environmental and economic challenges in the current recycling systems.

A Systems-based Sustainability Assessment Framework to Capture Active Impacts in Product Life Cycle/ Manufacturing

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Abstract

Impacts associated with various product life-cycle phases can be characterized geographically and classified as embodied or active; embodied impacts are accounted for in the realization of a product, e.g., water used in manufacturing; active impacts occur during use and post-use phases, e.g., microfibers in the living tissues of aquatic life. Active impacts can often be more significant than embodied impacts. Embodied impacts are easy to quantify and regulate through efficiency-based measures; whereas active impacts are difficult to trace and quantify, requiring an effectiveness-based approach. Active impacts have greater bearing on sustainability and require systems-based approach to discern causality of impacts traceable to manufacturing/design. Further, current sustainability assessment (SA) tools inadequately trace geographically distributed nature of product life-cycle phases and associated impacts. This paper discusses a systems-based SA framework for manufacturing to capture and trace active impacts to the corresponding

life-cycle phases, currently limited to acute and chronic impacts on societal health. The same methodology could be extended, subsequently, to accommodate economic and environmental impacts (of concern).

Hybrid Exergetic Analysis-LCA Approach and the Industry 4.0 Paradigm: Assessing Manufacturing Sustainability in an Italian SME

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Abstract

Assessing sustainability of manufacturing is a fundamental prerequisite to the improvement of efficiency or effectiveness of manufacturing processes. The LCA is used to estimate the resource consumption along the life-cycle, while the exergy analysis introduces hints about the quality of resource consumption. The hybrid analysis descending from combining these two approaches has been proved to be a powerful tool to recognize the process optimization opportunities, as well as improvements and/or innovation paths of manufacturing processes. The incoming Industry 4.0 paradigm, providing new on-time information on the process status, is going to strongly improve this approach. The article analyzes the existing hybrid approaches and their potential features by the grace of an industrial case of an Italian SME where the Industry 4.0 is taking place. The company redesigned its sensing systems and partially the manufacturing organization as a function of the manufacturing predictability.

Exploring the Relationships between Product Innovation Radicality and Extensity of Flexibility in Sustainable Manufacturing System: How Flexibility affects the Performance of Most Innovative Factories in the USA

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Abstract

This study aims to verify the relationship between product innovation radicality and extensivity of flexibility in sustainable manufacturing systems. In addition, this research examines how the flexibility affects the performance of most innovative factories in different sectors, in the USA, in the period from 2011 to 2017. A conceptual framework is drawn up based on the literature and confirmed with 115 specialists. To reduce subjectivity in the results achieved the following methods are used: psychometric scaling method, multi-criteria analysis: Compromise Programming, Electre III and Promethee II, and neurofuzzy technology. Finding of the study revealed that radicality in product innovation and extensivity of flexibility have a strong relationship. The study also found the high effect on the business performance.

Session 29: Sustainable Products -
Product (Re)Design for Circular Economy

Introducing Product Service System Architectures for realizing Circular Economy

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Abstract

Product-Service Systems (PSS) as well as modular products can act as an enabler for Circular Economy (CE). Products and services have to be developed concurrently in order to be attuned properly. In product design, developers have to fulfil various requirements such as functional and cost targets. Integrating requirements regarding CE and developing products and services simultaneously makes their task even more complex and challenging. In concept design, the outline or rough concept of the product is defined. In order to develop functional PSS and to integrate CE goals in the stage of concept design, the authors propose Integrated Product Service Systems Architectures (IPSSAs), which depict physical product architectures and services architectures in one integrated model. This paper presents first findings on how IPSSAs can be realized. An analysis of different modelling notations was conducted and an exemplary application on a use case was performed. The findings lead to further research steps on the path to a method for modularizing PSS for CE.

A Simulation Model of Consumer Take-Back Decisions Regarding Product Design

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Abstract

Companies utilize reverse logistic (RL) networks in order to reduce their carbon emission and increase their contributions to sustainability. Utilization of these networks heavily depends on product design, end-of-life options, and consumer decisions on product take-back. Joint consideration of consumer decisions and RL networks to enhance sustainability in products is where this study contributes to the literature. We develop a hybrid agent-based and discrete event simulation model to explore the impact of consumer decisions on total cost and carbon emission at the early stage of product design. The agent-based model simulates the consumer decisions on product take-back systems in order to determine the quantity of returns while the discrete event simulation models the end of life (EoL) options for products. Different product design options are incorporated to the model to investigate the impact of modularity on quantity of returns, total cost, and carbon footprint.

Effectiveness of Product Recovery Systems

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Abstract

Most consumer waste produced is from consumable products that end up in the general waste stream. To divert some of these products from the waste to recycling stream relies on separation at the point of disposal. Product stewardship programs are in place to increase the capture of some end of life products for reuse and recycling. However, these programs are reliant on the behavior of consumers at the disposal stage of the product life cycle. The work involves audit of the waste and recycling streams, and identifying the effectiveness of separation. A survey of consumers is conducted that tests their understanding of the recyclability of products. The work provides insights into the influences that increase the recycling rates for consumer products at the end of life.

Session 30: Sustainable Manufacturing Processes -
Energy and Resource Efficiency

Continuous Trajectory Planning for Welding of Complex Joints Using Bezier Curve

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Abstract

Sustainable manufacturing is now extensively cited in the literature; robotic technologies play a vital role in achieving it. The motivation for the use of industrial robots is mainly for their ability to execute programmed, tedious task, also to assist workers to perform boring and dirty jobs with the sole aim of advancing productivity and efficiency. For industrial robots to contribute to optimally to sustainable manufacturing, trajectory planning plays a key role in achieving this goal. In this paper, a Frenet Serret vectors are used to design a trajectory planning scheme for welding of complex joints, found in railcar manufacturing by using robotic welding application. The geometry of the complex path produce during arc welding is modelled as a Bezier spatial curve. An eight-order septic curve is used to interpolate the trajectory for a continuous motion a priori found in arc welding applications. The objective of the industrial robot manipulator is to follow a prescribed trajectory in the presence of imposed velocity and acceleration continuity constraints. Simulation is carried out to prove the validity of the proposed scheme.

Rotary Friction Welding versus Fusion Butt Welding of Plastic Pipes – Feasibility and Energy Perspective

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Abstract

According to the Plastics Pipe Institute, butt fusion is the most widely used method for joining lengths of PE pipe and pipe to PE fittings ”by heat fusion” (https://plasticpipe.org/pdf/chapter09.pdf). However, butt-welding is not energy-cognizant from the point of view of a phase-change fabrication method. This is because the source of heating is external (heater plate). The initial heating and subsequent maintenance at relatively high temperature (above 200 C for welding of high-density polyethylene pipe) is energy intensive. Rotary friction welding, on the other hand focuses the energy where and when as needed because it uses electric motor to generate mechanical (spinning) motion that is converted to heat. This work will make the case for friction heating as energy efficient. An initial feasibility study will also be introduced to demonstrate that the resulting welded pipe joints may be of comparable quality to those produced by butt fusion and to virgin PE material.

Minimizing Carbon Emission with Improved Human Health in Sustainable Machining of Austenitic Stainless Steel through Multi-Objective Optimization

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Abstract

Austenitic stainless steel is a difficult-to-cut material which is often used in applications such as aerospace, automotive, medical, construction and consumer products. However, high cutting forces and carbon emissions during machining make the machining process significantly more challenging. In industrial applications, typically flood-cooling (emulsion-based) utilizing conventional cutting fluids is applied, however it is generally known that these fluids are often harmful to both the operators and also the environment. Therefore, sustainable machining operations, such as dry, minimum quantity lubrication (MQL) and cryogenic (LN2) cooling, have been developed. Unfortunately, there is still a lack of understanding on how these cooling/lubrication strategies impact the carbon emission during machining. In this regard, this study presents a multi-objective optimization of cutting parameters in order to minimize the carbon emission with improved human health conditions in dry, MQL and cryogenic turning of austenitic stainless steel over a range of cutting conditions. The optimal results were obtained under cryogenic cooling with a cutting speed of 100 m/min for both objectives. In addition, the carbon emission can be reduced by applying cryogenic cooling at higher cutting speeds and lower undeformed chip thickness too.

Drivers and Barriers for the Adoption of Eco-Design Practices in Pulp and Paper Industry: A Case Study of Finland

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Abstract

This paper aims at defining, analyzing and evaluating barriers and drivers for eco-design implementation to the Finnish pulp and paper industry by using multi-criteria decision-making methods and consolidated ranking methodology. The drivers and barriers are identified through literature research and a survey is conducted for their evaluation. The results show that barriers more commonly present and interconnected in companies originate from internal management, while drivers often originate from external stakeholders. The paper concludes with policy recommendation, which will facilitate the adoption of eco-deign practices for sustainable manufacturing in the Finnish pulp and paper industry. The ranking of the barriers and drivers from different perspectives will help the decision-makers and managers in government and industry to mitigate these barriers in an effective manner.

Session 31: Sustainable Processes -
Manufacturing Processes, Tools and Equipment

Aggregating Unit Process Models to Enable Environmental Impact Characterization of Polymer-based Hybrid Manufacturing

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Abstract

The rapidly emerging field of additive manufacturing includes hybrid systems, which combine additive and subtractive operations. While advancements in hybrid technologies have been made – with a goal of enabling efficient large-scale production through reduced time-to-market, lower production costs, and shorter manufacturing process chains – relatively little attention has been paid towards characterizing associated environmental impacts. The work herein develops a methodology for aggregating unit manufacturing process models to characterize hybrid systems using ASTM 3012-16 (Standard Guide for Characterizing Environmental Aspects of Manufacturing Processes). The methodology is applied to characterize energy impacts of a low-cost, hybrid system for production of parts from polylactide (PLA), and compared with a conventional subtractive process (milling). The developed system produces near net-shape parts by employing a polymer filament extruder head (fused filament fabrication) integrated with a tabletop CNC mill. The part is milled to its final geometry using an endmill inserted into the CNC mill collet.

About the Use of Mineral and Vegetable Oils to Improve the Sustainability of Steel Quenching

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Abstract

The Die Assisted Oil Quenching process is a highly customisable heat treatment that permits a relevant reduction of distortions thus limiting or avoiding following grinding operations. Distortion reductions can be obtained not only by an action on process parameters and equipment but also by choosing suitable quenching media. Nowadays, the most widely used quenching fluids are mineral oils. Nevertheless, a number of innovative quenchants that are derived from oily plants are available on the market as possible alternatives to such media. Such multiplicity leads to a decision making problem that may deeply a↵ect the global sustainability of the process. In this paper, a comparative study between a mineral and a vegetable oil is performed. A preliminary analysis of the environmental impacts of the two quenching media is presented. Then, an experimental activity has been performed to investigate into the technical performances of the two media in terms of dimensional and metallurgical properties of the quenched parts. Furthermore, a

measurement of oily fogs has been performed during quenching to verify possible emission reductions. The experimental activity pointed out a better control of part distortions and a comparable metallurgical microstructure when vegetable oil is used for quenching. In addition, no oily fogs have been observed for this quenching medium.

Microstructural Effect of Laser Cladded Ti + TiB2 on Steel Rail

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Abstract

Rail is an important mode of transport and has proven to be a mobility system that is sustainable. The potential economic value of rail business is limitless. Trains steer by means of their wheel flanges around curves on a rail track. While speeding, this action produces high lateral and centrifugal forces, resulting in prolific wear on both the wheel flanges and the side of the rail crown unless this interface is lubricated. Uneven temperature generation was found along surfaces of the steel railhead. This often causes crack generation for wear to occur. Laser cladding techniques of additive technology were employed in this study. Ceramics of Titanium and Titanium diboride powders were made use of at different ratios on steel rail. Characterization of the cladded steel-rail samples was also done. This paper reveals the microstructural and phase transition of the laser cladded rail surface.

Keywords: Laser Cladding; Microstructure; Steel Rail; Wear; Wheel Flanges

Enhancing Accuracy and Productivity of Super Precision Turning Machining Centers

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Abstract

Modern super precision tuning centers have to provide accuracy in lower range of diamond turning machines (cylindricity under 1-2 micron) and high productivity, that diamond turning machines are not able to delivery because of their design limitations. High accuracy may be achieved if compensation of error will be compute based at feedback from results of part dimensions and profile measurement. At this moment are known systems that provide dimensional and sometimes profile feedback by results of measurement performed outside of cutting envelope of a turning center (lathe). For super precision turning centers with relative short duty cycles this approach is not effective. Super precision of turning center allows using it guide ways system as support for measuring device and perform in envelope measurement of part profile and dimensions. Information obtained during this measurement may be used for compensation of errors that are correlated to variation in cutting force as function of tool wear and variation of parts material characteristics in the batch.

This type of compensation has sense only when increase of turning center accuracy by any mechanical means will be too expensive or not achievable. Using an in envelope measuring system for error compensation may be justified only if machining center feed system has ability to perform small steps that are at least 0.1- 0.2 micron that is 5-10 times less that of required profile accuracy in the range of 1-2 micron.

Session 32: Crosscutting Topics in Sustainable Manufacturing - Education and Workforce Development

Analysis of Industrial Engineering Qualifications for the Job Market

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Abstract

As the emergence of advanced technologies such as artificial intelligence reshapes all sectors in the market, new approaches are necessary to help public and private institutions in order to get ready for the future faster. The digital transformation of the market force employees to adapt their working habits. This adaptation requires also a change in learning and teaching approaches for upcoming employees. This paper analyzes industrial engineering qualification and identifies the necessity for improving approaches in an educational program. Game-based learning is one of the educational approaches to promote learning for the digital transformation by setting goals, constraints, and payoffs. The selected serious game aims to teach undergraduate students how to manage the complexity of sustainable manufacturing by planning a factory beyond 2020.

A Systems Thinking Approach to Collaborations for Capacity Building and Sustainability in Engineering Education

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Abstract

The general decline in the retention of professionally qualified engineers in academia and industry vary from country to country and has been attributed to different reasons for industrialized and industrializing states. This paper focuses on the outcome from a Royal Academy of Engineering (RAEng) initiative in Sub-Saharan Africa, aimed at enriching engineering education through fostering strong links between industry and academia. A systems thinking model was developed to address the weaknesses and enhance the successes of the RAEng intervention in order to build capacity for sustainability in engineering education. The model was developed and based at the University of Zimbabwe as the hub, collaborating with 6 other regional universities. This paper advocates for scaling up the largely successful initiative while capitalizing on experiences and collaborations with institutions from the United Kingdom (UK) and envisaged partnerships with other institutions from Europe.

Promoting STEM Education through Sustainable Manufacturing: Case Study of Photovoltaic Toys

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Abstract

There is an increasing trend of renewable energy applications as a means of energy source in Tanzania. Many initiatives on renewable energy applications are focused at increasing their accessibility and usability preferably for electrification of Off-grid rural areas. In addition to providing eco-friendly energy supply, renewable energy applications have a great potential in addressing other socio-economic challenges including motivation of students to pursue Science, Technology, Engineering and Mathematics (STEM) subjects and careers.

A pilot project was conducted to examine the use of the renewable energy application as a tool for promoting STEM subjects to secondary school students in Tanzania. Through sustainable manufacturing approach, a sample of three different photovoltaic toys was produced by re-designing second-hand toys together with re-using waste-broken solar panels. This serves as an edutainment to enhance STEM teaching and learning that can easily and sustainably be adopted with the local context.

Session 33: Sustainable Manufacturing Processes -
Manufacturing Processes, Tools and Equipment

Belt Grinding of Cast Iron without Cooling Lubricant

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Abstract

In times of industrial globalization, the demand for more specialized and diverse product portfolios is leading to a shortage of resources. Against this background, the need for adaptable and resource-saving production processes is increasing. Belt grinding can hereby make a major contribution as one of the last steps in the production value chain. Thanks to its flexible tool system consisting of a contact element and an abrasive belt, this process can be applied to an extremely wide range of machining tasks. Recently, the great potential of diamond abrasive belts in machining high performance materials, such as Inconel, has been demonstrated. In comparison to conventional abrasive belts advantages arise over an increased tool life and higher productivity. By an appropriate choice of process parameters it is possible to dispense with cooling lubricants due to the thermal conductivity of diamond. Consequently the absence of expensive lubricant management periphery systems reduces health and environmental risks. The present work provides first insights into the possibilities of machining mass materials such as cast iron with diamond abrasive belts.

Increasing the Productivity and Quality of Flute Grinding Processes through the Use of Layered Grinding Wheels

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Abstract

Due to the increasing relevance of resource efficiency, the production of cutting tools is exposed to increasing demands in regard to productivity and quality. Flute grinding is of particular significance within the various grinding operations used in tool manufacturing. Apart from the rake face, the flute grinding process determines the quality of the cutting edges. However, the grinding wheels typically used for flute grinding are not designed to take the complex contact conditions of this process into account. This paper presents a method for designing application-oriented grinding wheels to improve the productivity and the quality of grinding processes. Firstly, a model is presented which is used to simulate the contact conditions. The results show the significance of the grinding wheel edge in flute grinding. Based on that, grinding wheels with different layers over its width were developed to compensate the varying and complex contact conditions. To verify this approach technological experiments were carried out.

Interaction of Tool and Workpiece in Ultrasonic-assisted Grinding of High Performance Ceramics

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Abstract

Ultrasonic assisted grinding processes promise high potential for economical machining of brittle hard materials and improved workpiece qualities. Especially in machining of high performance ceramics as well as ceramic matrix composites (CMC) a significant decrease of process forces and increased material removal rates can be achieved. In previous publications the fundamental effect mechanisms related to ultrasonic assistance in grinding processes were described. However, implicit knowledge about the influence of the tool specifications and geometry on the maximum achievable ultrasonic amplitude is lacking. Furthermore, knowledge about the behavior of the high-frequency tool motions during tool engagement could simplify the design of ultrasonic assisted grinding processes. A targeted utilization of ultrasonic effects can be result in lower process forces, less tool wear and shorter machining times which lead consequently to more sustainable processes. The presented work provides results of the interactions of tool design, tool contact conditions and workpiece in the ultrasonic assisted machining of ceramics with mounted points.

Session 34: Sustainable Manufacturing Processes - Cutting Technologies

Comparison between Elastomeric Passive Isolators and LQR Control in Stone Cutting Process: Modelling and Simulation

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Abstract

This paper focuses on the problem of mechanical vibrations induced in the cutting process of stone and marble in stone cutting machines. The study leads to sustainable stone cutting operations by saving energy, further finishing and providing noise clean environment. This periodic force induced in the cutting area is reduced passively by using an elastomeric pad that isolates the base of the machine from the head and the table. Adding less than 2.5% of passive damping ratio to the isolator could reduce the level of vibration on the saw blade and on the table. To reduce the propagation of these vibrations through the base into the floor, another elastomeric pad is mounted under the machine. This pad reduces the propagation of oscillations through the floor to the other places in the factory. Another solution is presented to reduce the vibrations in the whole structure significantly by regulating the input force this one is controlled by the LQR method. The controller has the capability to regulate the vibrations in the structure by solving the Riccati equation to compute the optimal response for the input force to perform the required tasks.

An Investigation of Buzz Saw Blade Cutting Forces Depending on Tool Geometry for Cutting Frozen Wood

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Abstract

Sawing processes in sawmills are characterized by high consumption of electric energy. Buzz saw blades, which are cutting tools with geometrically defined cutting edges, have a direct influence on the process efficiency and thereby on the electric energy consumption of cutting processes. Both are directly linked to cutting forces, which are determined by the geometry of the sawtooth as well as the material properties of wood. Especially in environments with sub-zero temperatures, the moisture in frozen logs is a crucial influence on the material properties. By the fact the hardness of ice increases exponentially along temperature decreases, the efficiency of cutting processes for cutting frozen wood decreases, too. In this paper, the cutting forces for cutting frozen wood depending on tool geometries are investigated. Based on these results, special tool geometries for buzz saw blades can be designed to increase the sustainability of industrial sawing processes for cutting frozen wood.

Sustainable Cooling and Lubrication Strategies in Machining Processes: A Comparative Study

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Abstract

Applying an adequate cooling and lubrication technique during machining processes is an important issue which affects the machining system efficiency. Flood cooling offers an effective solution to reduce the effect of the high generated heat during cutting processes; however, it isn't a sustainable strategy because of the health and environmental concerns associated with its utilization. Therefore, several cooling and lubrication strategies have been suggested and used as alternatives to the flood cooling. These strategies include; dry cutting, cryogenic approach, minimum quantity lubrication (MQL), nano-cutting fluids, and MQL-nano-fluids. In this work, a comparative study is presented to evaluate the sustainability effectiveness of these strategies. In order to evaluate the strategies effectiveness, five sustainability indicators are used; namely, energy consumption, personal safety and health, waste management, machining costs, and environmental impact. A weighted decision matrix is developed to assess the studied strategies in terms of the employed sustainable indicators.

Effects of Surface Texture Parameters of Cutting Tools on Friction Conditions at Tool-Chip Interface during Dry Machining of AISI 1045 Steel

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Abstract

Dry machining is one of the essential steps towards achieving sustainable manufacturing processes. Sustainable dry machining can be further enhanced by using surface textured cutting tools where the micro-capillary networks on cutting tool surfaces are exploited for tribological benefit in the absence of cutting fluids. This paper presents the results of an experimental study in which rake surfaces of uncoated carbide cutting tools are textured at different levels, and orthogonal machining is performed on AISI 1045 steel under dry machining condition. The results show that skewness, kurtosis, and other surface texture parameters on the rake surface significantly influence the machining forces via altering friction conditions at the tool-chip interface. Further, the orientation of the cutting tool's surface texture pattern has a strong effect on the capability of the surface micro-capillary network to allow atmospheric air, which must serve as a lubricant in dry cutting, to access portions of the tool-chip contact zone.

Session 36: Crosscutting Topics in Sustainable Manufacturing - Industry 4.0 and Sustainable Manufacturing

Induction Motor Condition Monitoring for Sustainable Manufacturing

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Abstract

As the power source for virtually all manufacturing systems, induction motor represents an integral part in modern manufacturing. Reliable functioning of induction motors is critical to minimizing machine downtime and maintaining high performance, which contributes to scrap-free production and overall sustainability in manufacturing. Due to the complex physical mechanisms, reliable and low-cost motor condition monitoring has remained a challenge, especially for small and medium-sized manufacturers (SMMs). This paper describes a data-driven method for real-time induction motor condition monitoring and fault diagnosis, based on Dictionary Learning and Nystrom method. The integrated method is highlighted by improved data discriminability and effectiveness in handling data high dimensionality. Experimental evaluation using vibration signal as fault indicator confirmed high accuracy of the proposed method in induction motor multi-fault classification and an 80% reduction in execution time.

Machine Learning in Cutting Processes as Enabler for Smart Sustainable Manufacturing

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Abstract

Machine learning is becoming an increasingly popular concept in the modern world since its most common goal is to optimize systems by allowing one to make smarter use of products and services. In the manufacturing industry machine learning can lead to cost savings, time savings, increased quality and waste reduction. At the same time, it enables systems to be designed for managing human behaviour. This research study used a systematic review to investigate the different machine learning algorithms within the sustainable manufacturing context. The study focuses specifically on cutting processes.

Knowledge Based Approach to Managing Industrial Energy

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Abstract

This presented text explains the cycle of energy management within an industrial production facility. The research addresses, the energy acquisitions in its different forms of fossil (natural gas) and electric (from the grid); in addition to landfill gas contribution. The energy conversions and final forms (pneumatic, thermal and electric) are also explained and their routes and efficiencies described. The research then presents a knowledge based management system to optimize the energy flows and strategies; this is done using a linear programming optimizer that renders different strategies under different objectives; mainly energy-efficiency, cost-effectiveness. The paper will also introduce the use of a rule-based logic framework to predict energy trends and plan ahead. Specific energy saving strategies will be highlighted and their impact on the overall facility Energy Performance Index EPI is computed.

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