

Lecture Notes in Production Engineering

Konrad von Leipzig  
Natasha Sacks  
Michelle Mc Clelland *Editors*

# Smart, Sustainable Manufacturing in an Ever-Changing World

Proceedings of International Conference  
on Competitive Manufacturing (COMA '22)

 Springer

# Lecture Notes in Production Engineering

## Series Editors

Bernd-Arno Behrens, Leibniz Universitaet Hannover, Garbsen, Niedersachsen, Germany

Wit Grzesik , Opole, Poland

Steffen Ihlenfeldt, Institut für Werkzeugmaschinen und, TU Dresden, Dresden, Germany

Sami Kara, Mechanical & Manufacturing Engg, University of New South Wales, Sydney, NSW, Australia

Soh-Khim Ong, Mechanical Engineering, National University of Singapore, Singapore, Singapore

Tetsuo Tomiyama, Tokyo, Japan

David Williams, Loughborough, UK

**Lecture Notes in Production Engineering (LNPE)** is a new book series that reports the latest research and developments in Production Engineering, comprising:

- Biomanufacturing
- Control and Management of Processes
- Cutting and Forming
- Design
- Life Cycle Engineering
- Machines and Systems
- Optimization
- Precision Engineering and Metrology
- Surfaces

LNPE publishes authored conference proceedings, contributed volumes and authored monographs that present cutting-edge research information as well as new perspectives on classical fields, while maintaining Springer's high standards of excellence. Also considered for publication are lecture notes and other related material of exceptionally high quality and interest. The subject matter should be original and timely, reporting the latest research and developments in all areas of production engineering. The target audience of LNPE consists of advanced level students, researchers, as well as industry professionals working at the forefront of their fields. Much like Springer's other Lecture Notes series, LNPE will be distributed through Springer's print and electronic publishing channels. To submit a proposal or request further information please contact Anthony Doyle, Executive Editor, Springer ([anthony.doyle@springer.com](mailto:anthony.doyle@springer.com)).

Konrad von Leipzig · Natasha Sacks ·  
Michelle Mc Clelland  
Editors

# Smart, Sustainable Manufacturing in an Ever-Changing World

Proceedings of International Conference  
on Competitive Manufacturing (COMA '22)

*Editors*

Konrad von Leipzig  
Department of Industrial Engineering  
Stellenbosch University  
Stellenbosch, South Africa

Natasha Sacks  
Department of Industrial Engineering  
Stellenbosch University  
Stellenbosch, South Africa

Michelle Mc Clelland  
Department of Industrial Engineering.  
Stellenbosch University  
Stellenbosch, South Africa

ISSN 2194-0525

ISSN 2194-0533 (electronic)

Lecture Notes in Production Engineering

ISBN 978-3-031-15601-4

ISBN 978-3-031-15602-1 (eBook)

<https://doi.org/10.1007/978-3-031-15602-1>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2023

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

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

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

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

# International Program Committee

## Conference Chair

K. Von Leipzig, Stellenbosch University, South Africa ([kvl@sun.ac.za](mailto:kvl@sun.ac.za))

## Co-chairs

V. Hummel, Reutlingen University, Germany ([Vera.Hummel@Reutlingen-University.DE](mailto:Vera.Hummel@Reutlingen-University.DE))

N. Sacks, Stellenbosch University, South Africa ([natashasacks@sun.ac.za](mailto:natashasacks@sun.ac.za))

## International Program Committee

F. Ansari, Technical University of Vienna, Austria

L. Bam, Stellenbosch University, South Africa

A. H. Basson, Stellenbosch University, South Africa

T. Becker, Stellenbosch University, South Africa

D. Blaine, Stellenbosch University, South Africa

A. Braun, Reutlingen University, Germany

J. B. Byiringiro, Dedan Kimathi University of Technology, Kenya

I. Campbell, Loughborough, England

P. Conradie, Stellenbosch University, South Africa

O. Damm, LHA Management Consultants, South Africa

C. J. du Plessis, Spatial Edge, South Africa

N. du Preez, Stellenbosch University, South Africa

C. J. Fourie, Stellenbosch University, South Africa

R. Genga, University of the Witwatersrand, South Africa

J. L. Jooste, Stellenbosch University, South Africa  
R. Knutsen, University of Cape Town, South Africa  
K. Kruger, Stellenbosch University, South Africa  
L. Louw, Stellenbosch University, South Africa  
D. Lucke, Reutlingen University, Germany  
E. Lutters, University of Twente, The Netherlands  
R. Machaka, CSIR, South Africa  
C. Machio, CSIR, South Africa  
S. Matope, Stellenbosch University, South Africa  
A. N. Mindila, Jomo Kenyatta University of Agriculture and Technology, Kenya  
S. Moseley, Hilti Corporation, Liechtenstein  
K. Mporfu, Tshwane University of Technology, South Africa  
O. M. Muvengi, Jomo Kenyatta University of Agriculture and Technology, Kenya  
R. Ndeda, Jomo Kenyatta University of Agriculture and Technology, Kenya  
J. Niemann, Hochschule Düsseldorf, Germany  
P. Nunthavarawong, King Mongkut's University of Technology North Bangkok, Thailand  
E. Olakanmi, BIUST, Botswana  
O. Omonigho, Federal University of Petroleum Resources, Nigeria  
D. Palm, Reutlingen University, Germany  
A. Pislă, Technical University in Cluj-Napoca, Romania  
P. Plapper, Technical University Luxembourg, Luxembourg  
S. Schlund, Technische Universität Wien, Austria  
K. Schreve, Stellenbosch University, South Africa  
W. Sihn, TU Vienna, Austria  
V. Stich, RWTH Aachen, Germany  
J.-M. Tarrago, Hilti Corporation, Germany  
L. Tshabalala, CSIR, South Africa  
K. Tuchinda, King Mongkut's University of Technology North Bangkok, Thailand  
L. van Dyk, North West University, South Africa  
A. Venter, NECSA, South Africa  
K. Wegener, ETH Zurich, Switzerland

## About CIRP

**CIRP** was founded in 1951 with the aim to address scientifically, through international cooperation, issues related to modern production science and technology. The International Academy of Production Engineering takes its abbreviated name from the French acronym of College International pour la Recherche en Productique (CIRP) and includes some 600 members from 50 countries. The number of members is intentionally kept limited, so as to facilitate informal scientific information exchange and personal contacts.

CIRP aims, in general, at:

- Promoting scientific research, related to
  - manufacturing processes,
  - production equipment and automation,
  - manufacturing systems, and
  - product design and manufacturing
- Promoting cooperative research among the members of the academy and creating opportunities for informal contacts among CIRP members at large
- Promoting the industrial application of the fundamental research work and simultaneously receiving feedback from industry, related to industrial needs and their evolution.

CIRP has its headquarters in Paris, staffed by permanent personnel, and welcomes potential corporate members and interested parties in CIRP publication and activities in general.

CIRP Office, 9 rue Mayran, 75009 Paris, France. Web: <http://www.cirp.net>.



# Foreword

Welcome to the eighth International Conference on Competitive Manufacturing hosted by the University of Stellenbosch and organized by the Department of Industrial Engineering.

The recent COVID pandemic yet again illustrated the interconnectedness of countries, companies, and individuals and also highlighted the dependencies on one another. In a small world where global trade is a given, international competitiveness stays a challenge. It requires high-quality products manufactured with state-of-the-art technologies at low cost under the assumption of highly efficient operations management as well as clear corporate goals and strategies. This in turn is facilitated by and dependent on improved engineering training, education, and relevant applied research, fueled by active interaction between academia and industry.

The main objective of COMA '22, the International Conference on Competitive Manufacturing, is to present recent developments, research results, and industrial experience accelerating improvement of competitiveness in the field of manufacturing. The close to 80 papers and presentations invited or selected to be delivered at the Conference deal with wide aspects related to product design and realization, production technologies and systems, operations management as well as enterprise design and integration. The worldwide participation and range of topics covered indicate that the Conference is truly a significant meeting of people striving for similar aims. The event is an additional opportunity for communication between paper authors and attendees, which undoubtedly will serve as a further step toward exciting developments in the future. It also provides ample opportunities to further exploit international research collaboration and collaboration between academia and practice. As in the past, we hope that the event will lead to tangible new outreach endeavors not only between existing collaborators, but also opening new opportunities to stimulate increased productivity and entrepreneurial ideas, so vital for an economy challenged by the COVID pandemic.

The chairmen and the organizing committee express heartfelt thanks and gratitude to the members of the international program committee, who have given their help and expertise in refereeing the papers and will chair the plenary and technical sessions during the Conference, as well as to the authors for participating and ensuring that

the high standards required on an International Conference were maintained. These thanks and gratitude are extended to our highly regarded plenary speakers.

The chairmen convey sincere thanks to the conference sponsors for their generous support, which made this event possible.

The International Academy of Production Engineering (CIRP) is gratefully acknowledged for the scientific sponsorship given to the Conference.

Finally, the tremendous effort of the organizing committee is appreciated. Grateful thanks are due particularly to the Conference secretariat for ensuring the success of COMA '22.

We hope that you will find the Conference interesting and stimulating!

Stellenbosch, South Africa

Mr. K. H. von Leipzig  
Conference Chair

# Submission Review Process

A formal “Call for papers” for the 8th International Conference on Competitive Manufacturing (COMA '22) was issued in May 2021 to submit an ‘Abstract’ within the identified tracks/themes. Abstract submissions were subjected to an internal reviewing process, whereby successful submissions were notified and invited for presentation to the conference. Authors were subsequently invited to submit the ‘Full Paper’, which was published as a conference proceeding. Both the Abstracts and Full Papers were submitted online through the EasyChair submission page <https://easychair.org/my/conference?conf=coma22> where acknowledgement of receipt was sent to authors. Authors were informed that a double-blind review process is applied to Full Paper submissions.

The following dates were set by the organising committee:

- Call for papers (1st May 2021)
- Submission of abstracts (12th July 2021)
- Notification of acceptance of abstracts (16th July 2021)
- Submission of full papers (28th January 2022)
- Feedback on paper reviews (8th February 2022)
- Revised paper submissions (15th February 2022)

Abstracts were required to be a maximum length of 400 words. Full Papers were required to be a maximum length of 6 pages, but leniency was given for the Author biographies and references. Full Paper submissions were required to adhere to a specific template and format which was placed on the conference site here: <https://blogs.sun.ac.za/coma/callforpapers/>.

A double-blind reviewing process was used for the Full Paper submissions. As such, both the reviewer and author identities are concealed from the reviewers, and vice versa, throughout the review process. Each Full Paper submission was sent to a minimum of two reviewers, with a third reviewer being requested in case of non-consensus between the first two reviewers. The reviews were completed by national and international academics, and experts in the respective field, listed on the International Programme Committee page.

A total of 45 reviewers participated in the review process, each reviewing between two and five papers. Reviewers were asked to review submissions according to the following criteria and were encouraged to provide recommendations and suggestions

- Does the title reflect the contents of the paper?
- Does the paper relate to what has already been written in the field?
- Do you deem the paper to be proof of thorough research and knowledge of the most recent literature in the field of study?
- Is the paper clearly structured, easy to read and with a logical flow of thought?
- Are the arguments employed valid and supported by the evidence presented?
- Are the conclusions clear and valid?
- Does the paper conform to accepted standards of language and style?
- Any other recommendation(s)?
- Select reviewer recommendation: 'Accept Submission', 'Revision Required', or 'Decline Submission'

Reviewer feedback was saved on the submission system, where acceptance emails together with review comments were sent to the authors, allowing them to revise the submission. The authors were given between 2 and 4 weeks to incorporate changes, after which the final document was submitted for approval and publication as a conference proceeding.

## Topics

Papers were invited in the following areas relevant to the conference themes:

### **Product Design and Realisation:**

Design for manufacturing and assembly, reverse engineering, CAD/CAE, concurrent engineering, design for additive manufacturing, biologically inspired design approaches, virtual prototyping, networks in product development, open design.

### **Production Technologies:**

Expert systems in manufacturing, CAD/CAM Systems, HSC, EDM, forming, additive manufacturing, casting, metrology, mechatronics, precision manufacturing, bio-manufacturing, robotics, sensing, assembly, automation, intelligent manufacturing, biologically inspired manufacturing processes, non-conventional machining, environmental aspects, machining of materials, abrasive processes, hybrid processes, laser-based manufacturing, green manufacturing, coating technology.

### **Production Systems and Organisations:**

Production planning and control, logistics, modelling and simulation, SW-applications, communication networks, 5G network applications, social manufacturing, learning factory, digital factory, biological transformation in production systems, cyber-physical approaches, big data, predictive maintenance,

asset management, human-machine collaboration, employee qualification, human resource management, IoT in manufacturing, manufacturing digitization challenges, augmented and virtual reality, lean manufacturing, sustainable manufacturing.

**Enterprise Design and Integration:**

Knowledge management, product life cycle, human interface, integrated design and manufacturing, technology and innovation management, total quality management, distributed control systems, socio- economic and environmental issues, artificial intelligence and machine learning, digital twins, virtual setup, subscription vs selling.

**Supply Chain Management:**

Supply chain track and tracing; digital supply networks, blockchain in supply chains, circular economy, artificial intelligence for supply chains, biological transformation in supply chains.

**COVID-19: Manufacturing and Supply Chain:**

Post-pandemic business models, Supply chain localisation, manufacturing as a service, Rapid medical device manufacturing, Distributed manufacturing, Constrained supply chains, Resilient supply chains.

**Materials and Manufacturing:**

Smart materials, Recycling, Remanufacturing, Future materials, Biomaterials, Sustainable materials, Nanomaterials, Coatings, Metal matrix composites.

# Acknowledgements

Sincere thanks to our distinguished supporters and sponsors, whose generosity made possible the success of this Conference.



# Contents

<b>Production Systems and Organizations</b>	
<b>Identification of Residual Development Efforts in Agile Ramp-Up Production</b> .....	3
Thomas Bergs, Sebastian Apelt, Malte Becker, Alexander Beckers, and Sebastian Barth	
<b>Cross-Process Modeling of Manufacturing Process Sequences with Consideration of Model Uncertainties</b> .....	17
Thomas Bergs, Alexander Beckers, Sebastian Apelt, Tim Hommen, and Sebastian Barth	
<b>Modeling Interactions and Dependencies in Production Planning and Control</b> .....	31
Alexander Mütze, Simon Lebbing, Simon Hillnhagen, Matthias Schmidt, and Peter Nyhuis	
<b>ARTI-Based Holonic Manufacturing Execution System Using the BASE Architecture: A Case Study Implementation</b> .....	45
A. Wasserman, K. Kruger, and A. H. Basson	
<b>Production Systems and Organizations II</b>	
<b>Bridging the Gap Between Digital Human Simulation to Standard Performance with Human Work Design</b> .....	61
Peter Kuhlmann, Martin Benter, and Maria Neumann	
<b>Interface Holons in the BASE Architecture for Human-System Integration in Cyber-Physical Systems</b> .....	71
D. J. van Niekerk, K. Kruger, and A. H. Basson	
<b>Design and Construction Framework to Enable the Modular Block Building Methodology to Broaden South African Oceans Economy</b> .....	85
H. Theunissen, T. Van Niekerk, and J. H. C. Pretorius	

**Production Controlling Governance to Ensure Homogenous Information Systems and Targeted Decision-Making Processes** ..... 97  
T. M. Demke, A. Mütze, and P. Nyhuis

**Automation, Human–Machine Interaction, Interfaces**

**Sustainable Utilization of Industrial Robotic Systems by Facilitating Programming Through a Human and Process Centred Declarative Approach** ..... 111  
Titanilla Komenda, Jorge Blesa Garcia, Maximilian Schelle, Felix Leber, and Mathias Brandstötter

**Productivity Driven Dynamic Task Allocation in Human–Robot-Collaboration for Assembly Processes** ..... 123  
M. Euchner and V. Hummel

**Artificial Intelligence Based Robotic Automation of Manual Assembly Tasks for Intelligent Manufacturing** ..... 137  
Alexej Simeth and Peter Plapper

**Development of an AI-Based Method for Dynamic Affinity-Based Warehouse Slotting Using Indoor Localisation Data** ..... 149  
Jan Schuhmacher and Vera Hummel

**Enterprise Design and Digital Twins**

**A Framework for Leveraging Twin Transition in the Manufacturing Industry** ..... 163  
Lukas Stratmann, Volker Stich, Ruben Conrad, Gerrit Hoeborn, Felix Optehostert, and Minh Phuc Phong

**Virtual Reality for Interacting with a Manufacturing System Digital Twin—A Case Study** ..... 179  
Yafet Haile-Melekot, Karel Kruger, and Jörg Niemann

**Accuracy in Digital Twinning; An Exploration Based on Asset Location** ..... 191  
Eric Lutters and Roy Damgrave

**Simultaneous Multi-stakeholder Digital Twinning for Anticipated Production Environments** ..... 203  
R. G. J. Damgrave and E. Lutters



## **Novel Engineering Concept and Innovation**

### **A Digital Service Engineering Training Course to Raise Competitiveness in Advanced Service Industries ..... 217**

Jörg Niemann, Claudia Fussenecker, Martin Schlösser,  
and Dominik Kretschmar

### **Modern Project Approaches in Shortening the Lead Time in Innovation for Young Emerging Companies Based on the Experienced Seniors Knowledge ..... 229**

Adrian Pîslă, L. Nae, Calin Vaida, Eduard Oprea, Bogdan Gherman,  
Michel Deriaz, and Doina Pislă

### **Opportunities Presented by Industrial 4.0 Revolution to Revitalize the Railway Sector: A Review ..... 243**

Sinegugu Tshabalala and Khumubulani Mpofu

### **Hybrid Approach on the Project Development Within Automotive Industry ..... 251**

Ovidiu Popa, Cristian Făgărășan, Adrian Pîslă, Cristina Mihele,  
and Rus Felician

## **Human Integration**

### **The Application of ArchiMate for Planning the Implementation of Manufacturing Management Systems ..... 265**

D. W. Gibbons and A. F. van der Merwe

### **Overview of Design Dimensions for Ambidexterity in Manufacturing Innovation Management ..... 287**

Q. Gärtner and A. Dorth

### **Possibilities and Challenges for Human-System Integration in the South African Manufacturing Context ..... 301**

T. W. Defty, K. Kruger, and A. H. Basson

### **Systematization of Technological Capabilities for Connected Adaptive Production ..... 315**

Günther Schuh, Thomas Scheuer, and Jannik Herding

## **COVID-19 Manufacturing, Services, Business Models**

### **Did the Covid-19 Pandemic Improve Engineering Education?—A South African-German Perspective ..... 333**

Deborah Blaine, Claudia Fussenecker, Jörg Niemann, and Karin Wolff

### **Typology and Implications of Equipment-as-a-Service Business Models in the Manufacturing Industry ..... 347**

L. Holst and V. Stich

**Investigating the Shattering Index of Coal Fines Briquettes  
Produced with Natural Binders** ..... 357  
R. Nemukula and D. M. Madyira

**Kanban in Software Development—The Role of Leadership  
and Metrics** ..... 369  
C. Fagarasan, C. Cristea, C. Mihele, O. Popa, D. Ciceo, and A. Pisla

**Extended Reality**

**Application of Augmented Reality for the Training in the Field  
of Refrigeration and Air-Conditioning** ..... 387  
F. Bellalouna and R. Langebach

**Augmented Reality for Operators in Smart Manufacturing  
Environments: A Case Study Implementation** ..... 401  
T. Gramberg, K. Kruger, and J. Niemann

**Augmented Reality Combined with Machine Learning to Increase  
Productivity in Fruit Packing** ..... 415  
M. van der Westhuizen, K. H. von Leipzig, and V. Hummel

**Enterprise Design**

**Measuring the Impact of Sustainability of Product-Service-Systems** .... 435  
D. Kretschmar, J. Niemann, C. Deckert, and A. Pisla

**People, Process, Master Data, Technology: Data-Centric  
Engineering of Manufacturing Management Systems** ..... 447  
Thomas Gittler, Lasse Plümke, Francesco Silani, Pietro Moro,  
Lukas Weiss, and Konrad Wegener

**Derivation of Requirements for the Formation of Collective  
Target Systems for Technology-Based Cooperation Between  
Manufacturing Corporates and Startups** ..... 463  
G. Schuh and B. Studerus

**Resources Collaboration and Optimization in Industry 4.0  
Environments** ..... 483  
Elif Ocakci, Anca Draghici, and Jörg Niemann

**Production Systems and Maintenance**

**Investigation of Predictive Maintenance Algorithms for Rotating  
Shafts Under Various Bending Loads** ..... 497  
C. I. Basson, G. Bright, J. Padayachee, and S. Adali

**Analysis and Modelling of the Track Quality Index of Railways** ..... 511  
Stefan Laubscher and Johannes L. Jooste

**A Project Management Framework for the Modernisation of Passenger Railway Depots in Developing Countries** ..... 525  
Adquate L. Masikati, Johannes L. Jooste, and Cornelius Fourie

**A Gamified Learning Approach Using Systems Modelling for Understanding the Effects of Asset Management Decision-Making** ..... 537  
Ilicia M. Van Breda, Johannes L. Jooste, and Vera Hummel

**Supply Chain**

**Opportunities for Visualising Complex Data by Integrating Virtual Reality and Digital Twins** ..... 553  
G. S. da Silva, K. Kruger, and A. H. Basson

**Prototypical Blockchain Application for Mapping Complex Products in Dynamic Supply Chains** ..... 565  
F. Dietrich, L. Louw, and D. Palm

**Development of a Procedure Model to Compare the Picking Performance of Different Layouts in a Distribution Center** ..... 575  
Dorit Schumann, Cihan Cevirgen, Julian Becker, Omar Arian, and Peter Nyhuis

**Feasibility Assessment of 5G Use Cases in Intralogistics** ..... 587  
F. Dietrich, M. Angos Mediavilla, A. Turgut, T. Lackner, W. Jooste, and D. Palm

**Manufacturing Systems**

**Carbon Capture and Utilization in Cement Industry—Aspects of the Production of E-Fuels by Upcycling Carbon Dioxide** ..... 603  
Anika Wacht, Stefan Kaluza, and Philipp Fleiger

**A Procedure to Achieve Single Minute Exchange of Die for Cold Roll Forming** ..... 613  
T. Pillay, Glen Bright, Christian Basson, and Avern Athol-Webb

**Machine Learning for Soft Sensors and an Application in Cement Production** ..... 627  
Marcel Stöhr and Thomas Zielke

**Framework for Integrating Intelligent Product Structures into a Flexible Manufacturing System** ..... 639  
A. Burkart, G. Bitsch, and I. H. de Kock

**Manufacturing Technologies I**

**A Force Controlled Polishing Process Design, Analysis and Simulation Targeted at Selective Laser Melted Ti6Al4V Aero-Engine Components** ..... 655  
Quintin de Jongh, Matthew Titus, and Ramesh Kuppuswamy

**An Overview of Additive Manufacturing Research Opportunities in Transport Equipment Manufacturing** ..... 673  
Rumbidzai Muvunzi, Khumbulani Mpofu, and Ilesanmi Daniyan

**Dimensional Stability of Mineral Cast for Precision Machinery** ..... 685  
Eduard Relea, Lukas Weiss, and Konrad Wegener

**Effect of Mercerization on Coconut Fiber Surface Condition for Use in Natural Fiber-Reinforced Polymer Composites** ..... 701  
S. P. Simelane and D. M. Madyira

**Manufacturing Technologies II**

**Understanding the Structural Integrity and Post-processing of L-PBF As-Built Ti-6Al-4V Parts: A Literature Review** ..... 717  
W. M. I. Makhetha, G. M. Ter Haar, N. Sacks, and T. H. Becker

**Towards a Virtual Optical Coordinate Measurement Machine** ..... 737  
Z. Luthuli, K. Schreve, and O. A. Kurger

**Turn-Milled High-Friction Surfaces—Investigations on the Influence of Nominal Surface Pressure and Load Direction** ..... 749  
R. Funke and A. Schubert

**The Development and Inverse Kinematics of a 5 DOF Parallel Kinematic Architecture Machining System** ..... 763  
W. Dharmalingum, J. Padayachee, J. Collins, and G. Bright

**Smart Data**

**Driving Big Data Capabilities and Sustainable Innovation in Organisations** ..... 779  
Tanja von Leipzig, Jacques du Toit, and Frank Ortmann

**Indoor Positioning Using a Single PTZ Camera** ..... 797  
J. Hermann, A. H. Basson, K. H. von Leipzig, and V. Hummel

**Data Analytics in Industrial Engineering for Economic Sustainability: A Use Case on Planning and Controlling of Rework** .... 811  
Ralph Hensel, Thomas Mayr, and Mathias Keil

<b>Finite Element Analysis of the Stress Distribution in a Novel Brake Beam of a Railcar</b> .....	825
Ilesanmi Daniyan, Khumbulani Mpofu, Felix Ale, and Rumbidzai Muvunzi	
<b>Manufacturing Technology and Materials</b>	
<b>A Kinematics Study on a Ni-D Electroplating Process for Enhancing the SuperAbrasive Grinding Wheel Quality</b> .....	841
Sofian Eljzoli and Ramesh Kuppuswamy	
<b>The Effect of Minimum Quantity Lubrication on Selected Surface Integrity Attributes When Machining Grade 4 Titanium Alloy</b> .....	855
Alpheus N. Maponya and Rudolph F. Laubscher	
<b>Laser Shock Peening: A NbC Based Cermet Enhancement Alternative for Improved GCI Interrupted Face-Milling</b> .....	871
R. M. Genga, D. Glaser, P. Rokebrand, L. A. Cornish, M. Woydt, T. Gradt, A. Janse van Vuuren, and C. Polese	
<b>Evaluating the Relationship Between Powder Characteristics, Defects, and Final Build Properties for L-PBF WC-Co</b> .....	891
P. Govender, D. Hagedorn-Hansen, D. C. Blaine, and N. Sacks	
<b>Manufacturing Systems</b>	
<b>An Overview of the Manufacturing Systems: A Literature Survey</b> .....	905
Nokulunga Zamahlubi Dlamini, Khumbulani Mpofu, Ilesanmi Daniyan, and Boitumelo Ramatsetse	
<b>Research Endeavors Towards Predictive Modelling of a Grinding Process</b> .....	929
Fungai Jani, Samiksha Naidoo, Quintin de Jongh, and Ramesh Kuppuswamy	
<b>Role of Grinding Spark Image Recognition on Enhancing the Smart Grinding Technology for Ti6Al4V Alloy</b> .....	945
S. Naidoo, F. Jani, and Ramesh Kuppuswamy	
<b>Hybrid Production Principles: A Framework for the Integration in Aircraft Manufacturing</b> .....	957
Alexander Wenzel, Torben Lucht, and Peter Nyhuis	

# **Production Systems and Organizations**

# Identification of Residual Development Efforts in Agile Ramp-Up Production



Thomas Bergs, Sebastian Apelt, Malte Becker, Alexander Beckers,  
and Sebastian Barth

**Abstract** Agile product development is increasingly finding its way into the development of physical products. The subsequent transfer of a planned and still unstable manufacturing process into stable series production after the design freeze is the goal of ramp-up production, but confronts manufacturing companies with different challenges. A currently high level of changes to the product geometry and the planned manufacturing sequence due to not achieved requirements in late phases of the ramp-up production (Residual Development Efforts—RDE) results in time-consuming and cost-intensive changes to the product and manufacturing sequence, which leads to failure to achieve ramp-up targets. The goal of current research is therefore to increase the agility of ramp-ups and to integrate the ramp-up production into the phase of agile product development. This offers the potential to use the increased dynamics of the product development process and the knowledge already generated for the validation and stabilization of the manufacturing process. However, due to the integration of ramp-up production into product development, there are additional far-reaching effects of product and technology uncertainties prevalent in agile product development on the design of agile ramp-up production. Additional uncertainties regarding the product geometry due to non-finalized designs and the resulting

---

T. Bergs · S. Apelt (✉) · M. Becker · A. Beckers · S. Barth  
Laboratory for Machine Tools and Production Engineering WZL of RWTH Aachen University,  
Chair of Manufacturing Technology, Aachen, Germany  
e-mail: [s.apelt@wzl.rwth-aachen.de](mailto:s.apelt@wzl.rwth-aachen.de)

T. Bergs  
e-mail: [t.bergs@wzl.rwth-aachen.de](mailto:t.bergs@wzl.rwth-aachen.de)

M. Becker  
e-mail: [malte.becker@rwth-aachen.de](mailto:malte.becker@rwth-aachen.de)

A. Beckers  
e-mail: [a.beckers@wzl.rwth-aachen.de](mailto:a.beckers@wzl.rwth-aachen.de)

S. Barth  
e-mail: [s.barth@wzl.rwth-aachen.de](mailto:s.barth@wzl.rwth-aachen.de)

T. Bergs  
Fraunhofer Institute for Production Technology IPT, Aachen, Germany

uncertainties regarding the probability of use and achievement of the requirements of the manufacturing technologies initially result in additional residual development efforts. Furthermore, the interactions between the manufacturing technologies in the manufacturing sequence are thus subject to additional uncertainties, which also leads to increased RDEs. To meet this challenge, it is necessary to analyze prevailing uncertainties and predict their impact on potential changes in agile ramp-up production. Therefore, a methodology is presented, which enables the analysis of product and technology uncertainties and thus the identification of product and process-related changes (RDE) in agile ramp-up production.

**Keywords** Agile ramp-up production · Technology planning · Uncertainties · Residual development efforts · Manufacturing sequence

## 1 Introduction

In the course of globalization, manufacturing companies are confronted with various challenges in a dynamic competitive environment. These challenges include shorter product life cycles, changing customer requirements and increasing product variety [1]. In order to meet these challenges, an optimized product development process and a controlled transition from product development to series production, which is referred to as ramp-up production, are necessary [2]. The design freeze describes the point at which no more changes to the developed product are allowed and at which the release for the ramp-up production is set [3]. In conventional ramp-up production, which follows the design freeze, ramp-up targets are often not achieved. This means, for example, that the time-to-market and time-to-volume as well as the ramp-up budget are exceeded [4]. The non-achievement is due to instabilities in the manufacturing sequence, which are caused by fluctuating employee and technology capabilities on the one hand [5]. On the other hand, the instabilities are caused by residual development efforts in the ramp-up production. Residual development efforts are necessary subsequent developments to the product or to the technologies of a manufacturing sequence, which are based on insufficient product and technology maturity [2] as well as on an insufficient coordination between product development, technology planning and ramp-up management [3]. Manufacturing sequences describe the combination of value-adding process steps and handling technologies for the manufacture of a component [6]. It is difficult to address these challenges in the planning phase because manufacturing technologies are not physically connected to generate a manufacturing sequence until ramp-up production. Only through this connection previously unknown interactions between technology and product, but also between the technologies themselves, become visible [4].

Residual development efforts (RDEs) in ramp-up production are similar to constantly changing customer requirements in product development. Since the concept of agile product development is finding its way into product development to meet this challenge, current research focuses on the adaptation of agile methods



to the ramp-up production [4]. In agile product development, the scrum approach is widespread, which divides a development project into short development cycles, referred to as sprints [7]. The increase in agility and the integration of ramp-up production into agile product development is referred to as agile ramp-up production. On the one hand, the integration aims to enable improved coordination between product development, technology planning and ramp-up management. On the other hand, the ramp-up production should become more agile through agile product development, so that problems (like RDEs or instabilities of the manufacturing sequence) can be identified earlier to be counteracted. Due to the integration, the ramp-up production no longer starts after the design freeze. Therefore, uncertainties regarding the product are present in the agile ramp-up production [4]. Since the technologies for the manufacturing sequence are planned in parallel with product development, there are technology uncertainties as well. The challenge for technology planning in agile ramp-up production is to validate a manufacturing sequence planned under uncertainty based on uncertain information. As a consequence of agile ramp-up production, the existing uncertainties have to be analyzed to avoid additional residual development efforts.

To address this challenge, the state of the art regarding existing methods for ramp-up production and product development is analyzed and the objective of the developed methodology is presented. Subsequently, the methodology is explained in detail and validated in a case study.

## 2 State of the Art

For agile ramp-up production, it is necessary that both product development and ramp-up production are considered. In addition, the manufacturing sequence and residual development efforts must be taken into account. Due to the integration of ramp-up production into product development, uncertainties are present in agile ramp-up production, which must also be taken into account. In the scientific literature, a variety of approaches exist which address either the ramp-up production or the product development. Most of the analyzed approaches addressing ramp-up production describe it from an organizational and socio-technical point of view and neglect the manufacturing sequence and residual development efforts, such as the approaches of Laick [8], Winkler [9], Dyckhoff et al. [10]. The approaches of Lanza and Stauder consider manufacturing technologies as a part of a manufacturing sequences but handling technologies and residual development efforts are not sufficiently addressed [3, 5]. It is concluded that existing approaches regarding ramp-up production do not allow a comprehensive consideration of residual development efforts.

The following section analyzes approaches from product development and their transferability to agile ramp-up production. Examples of such approaches are Cooper et al. and Sommer et al. However, these approaches describe product development

from an organizational and socio-technical perspective [11, 12]. Rey's dissertation deals with the combination of technology planning and product development. Handling technologies and instabilities during ramp-up production are not considered [13]. Summed up, the ramp-up production is not considered in any of these approaches.

In addition to the described approaches, first approaches which consider both product development and ramp-up production exist, e.g. from Basse and De Lange. However, manufacturing sequences, modeling of uncertainties, and the identification of residual development efforts are not or insufficiently discussed [14, 15].

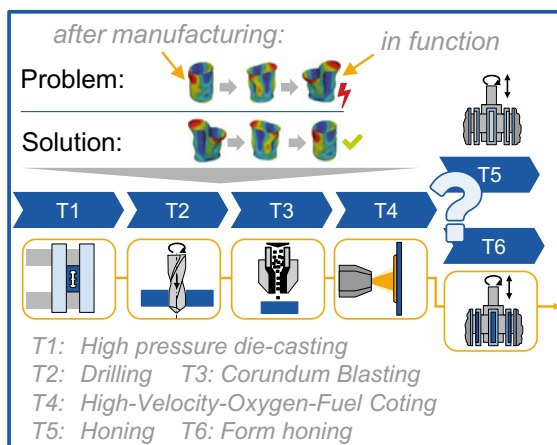
Conclusively, existing approaches do not allow a cross-phase consideration of product and technology uncertainties as well as a consideration of residual development efforts in agile ramp-up production. Furthermore, existing approaches neglect handling technologies in the manufacturing sequence. Therefore, a methodology is needed that considers the manufacturing sequence, product and technology uncertainties and the residual development efforts in the ramp-up production. This requires modeling product and technology uncertainties as well as predicting and evaluating residual development efforts in ramp-up production. The developed methodology is described in detail below.

### 3 Objective

The objectives of the methodology presented are to increase the agility of ramp-up productions and to enable users to systematically model existing uncertainties for the identification of residual development efforts under consideration of planned manufacturing sequences. For this purpose, uncertainties resulting from the integration of ramp-up production into product development must be taken into account in order not to additionally threaten ramp-up targets. The methodology enables the identification of problems at an early stage in the ramp-up production and the initiation of targeted measures to eliminate the problems. This improves target achievement during the ramp-up production and reduces the development time to series maturity.

### 4 Case Study

For a better understanding of the methodology, the details are given by means of a case study from industrial practice. As a consequence of the increasing demand for vehicles with low CO<sub>2</sub> emissions, legal regulations for the reduction of CO<sub>2</sub> emissions as well the high importance of a successful ramp-up production in the automotive industry, the validation of the developed methodology is carried out on the basis of a cylinder crankcase for an engine. One solution to the problem of reducing exhaust emissions and fuel consumption is to reduce friction. There is potential in optimizing the tribological system between the cylinder bore and the piston ring. The friction

**Fig. 1** Case study [16]

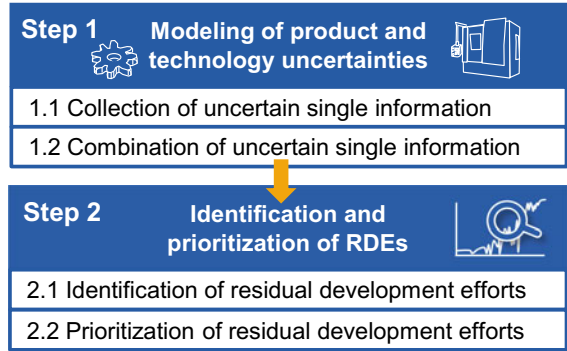
is largely dependent on the contour of the cylinder bore surface [16]. The aim is to manufacture the cylinder bore surface of the cylinder crankcase with a containment contour, see Fig. 1.

The development of the cylinder crankcase is conducted agile. Uncertainties exist with regard to the general use of a containment contour, the exact contour dimensions and shape, position and dimensional tolerances. In the case study, the containment contour could be realized by form honing (T6). However, there are uncertainties with regard to the tool life and the handling step that transfers the cylinder crankcases to the form honing technology. In order to achieve the shortest possible time to market, the ramp-up production is carried out in parallel with agile product development.

## 5 Methodology

In this section, the developed methodology is described. Uncertain manufacturing sequences and product characteristics represent the input of the methodology. The conceptual design of the methodology consists of two steps (see Fig. 2). In the first step, the uncertainty situation is modeled by collecting single information, which are afterwards combined to aggregated information. In the second step, RDEs are identified based on the modeled uncertainties, which are finally evaluated for the prioritization for the execution of prototype tests and validation in the ramp-up production. The output of the methodology are prioritized potential residual development efforts for which countermeasures have to be determined. The determination of countermeasures is not part of this paper. In the following, both steps are presented in detail.

**Fig. 2** Conceptual design of the methodology



**5.1 Modeling of Uncertainties**

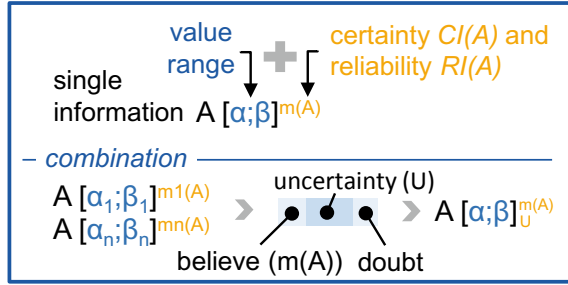
The understanding of uncertainty in this approach is based on the generalized information theory, in which the terms information and uncertainty are linked with each other. According to this theory, uncertainties are information deficits, which can be reduced by appropriate additional information [17]. Furthermore, in this approach, uncertainties are divided into product and technology uncertainties. Product uncertainties result from uncertain product characteristics. Technology uncertainties are information gaps for the manufacturing of product characteristics as well as for handling. This step serves to quantify existing uncertainties regarding the developing product and the manufacturing sequence. This step is modeled based on the methodology of Rey, which allows the combination of various individual pieces of information into product requirement and technology capability profiles [13].

**5.1.1 Collection of Uncertain Single Information**

The first step of the methodology is to collect information regarding product requirements and technological capabilities of the planned manufacturing and handling technologies. A single Information (A) can be acquired from various sources such as standards, journals, technical books or expert statements. The certainty of single information (CI) describes how certain an information source is when providing a single information. A certainty of 100% corresponds to the highest certainty of an information source regarding a single information, whereas a certainty of 0% corresponds to the lowest certainty. Furthermore, the user of the methodology determines the reliability of a single information (RI), see Fig. 3.

The reliability of a single information describes the percentage of trustworthiness of an information source. This is relevant, because different sources of information have different credibility [13]. Subsequently, the collected information is modeled using the evidence theory from Dempster [18] and Shafer [19].

**Fig. 3** Modeling on Uncertainties



In this theory of plausible reasoning, evidence describes an immediate insightfulness of findings and unprovable statements, for which the correctness can only be determined by their occurrence, or non-occurrence [20]. Evidence (also called base dimension) results from the certainty and reliability of the occurrence of a single piece of information (A). To do this, the certainty and reliability of a single information are multiplied, see formula (1) [13].

$$m(A) = CI(A) \cdot RI(A) \quad (1)$$

For example, an evidence of 100% results if an expert provides a single information with a certainty of 100% and the user of the methodology fully trusts this expert. In the case study introduced, one of the uncertainties is the tool life of the honing stones used in the manufacture of the cylinder crankcase. For this purpose, information is obtained from the design and technology planning departments, which differ in their credibility and in the specified interval range.

### 5.1.2 Combination of Uncertain Single Information

By combining different information from different sources, it is possible to generate an aggregate information considering the reliability of each source of information [20]. Thereby, fixed single values as well as value ranges can be specified by the information sources. By combining this single information (in the form of value ranges or single information), aggregated value ranges are evaluated with an uncertainty (based on the evidence). The uncertainty thus provides information about the certainty with which the final expression lies within the aggregated value (Interval). For this purpose, the combination rule of Yager [21] is used. This combination rule is a derivative of the combination rule according to Dempster [18], which is also suitable for processing contradictory information [21]. The result of the step is a combined information with a total certainty and uncertainty (U) [13]. Based on the case study, the information regarding the tool life from design and technology planning are combined. The result is a value range with a specified uncertainty that the actual tool life is assigned to. By acquiring more information, the range of values can be narrowed or the uncertainty can be reduced.

5.2 Identification an Periodization of Residual Development Efforts

In the second step of this methodology, residual development efforts are identified based on the previously modeled uncertainties. For this step, structural models are presented below, which allow the systematic identification of RDEs based on modeled uncertainties. The structural models offer the user a first point of reference for assistance and must be adapted to the considered manufacturing task. Subsequently, the identified residual development efforts are prioritized.

5.2.1 Identification of Residual Development Efforts

To identify RDEs, a fundamental distinction is made between product- and technology-driven uncertainties. Both structural models (product and technology) are analogous to a tree structure. The first level represents uncertainty classes to which the present uncertainties are assigned. Uncertainty classes based on product uncertainties are, for example, uncertainties regarding functionality fulfillment or geometric uncertainties. Regarding the use case, product uncertainty classes are differentiated into mechanical, hydraulic, pneumatic, electrical and magnetic, optical-physical, medical-biological, acoustic, optical-physical [22] and tribological [23] functionalities as well as geometrical uncertainties. Examples for classes of technology uncertainties are uncertain manufacturability, uncertain handling and uncertain process design (see Fig. 4).

The uncertainty classes are subdivided into subgroups (uncertain elementary function) on a second level, if possible. An elementary function is the smallest unit of a

Fig. 4 Structural models for the identification of RDEs

