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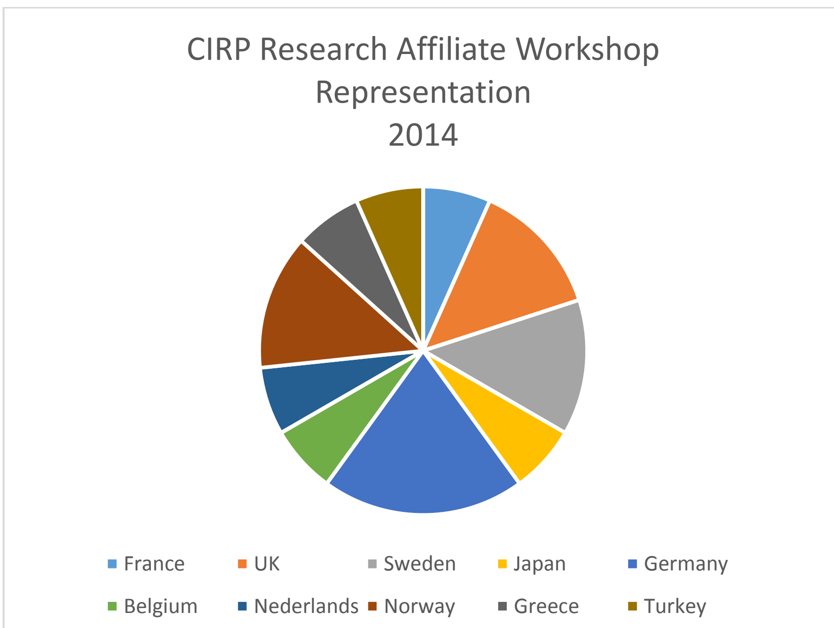
1. Summary

This It was an honor for me to host the 2014 CIRP research affiliate workshop at the Høgskole i Gjøvik, Norway on June 16th and 17th. Eleven research affiliates attended the workshop and the figure below provides an overview of the RA representation.



The workshop started with presentations from the RA's regarding their on-going research activities. This document marks the first Book of Abstracts for RA's and I sincerely hope that this is activity could be continued moving forward with the future workshops.

Rhythm Suren Wadhwa

2. Table of Contents

3. Overview of Abstracts

3.1 Design and process strategies for metal additive manufacturing

Wessel W. Wits (University of Twente, The Netherlands)

Additive Manufacturing (AM) is a relatively new type of production technology, where parts are typically build using a layered approach. AM enables the production of (near) net-shape parts with complex geometries, optimized structures and internal cavities. Compared to conventional processes, for AM the design and process strategies are not that well known yet; more so, for metal AM.

As AM technologies have the capability of producing parts impossible to produce otherwise, this poses new demands on the part design, process design and also on the quality control strategies. Freeform options, optimized geometries, porous structures and gradient properties, as shown in Figure 1, are functional part features that should now be on the repertoire of design engineers.

Figure 1: freeform optimized geometry with porous features.

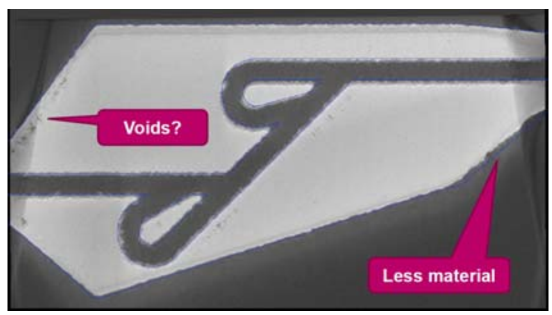


Figure 2: AM part and automatic CAD comparison (original CAD contour is blue).

This presentation focusses on the quality control of both outer (i.e. on the surface) and internal shapes. 2D x-ray imaging and 3D Computer Tomography (3D-CT) are addressed. The former being rather "quick and dirty". The latter allows us to examine the part in any plane or direction. Quality control algorithms can automatically determine part quality based on the original CAD file, as shown in Figure 2. Also, production defects, such as unwanted voids due to the additive process can be traced automatically. Finally, current research advances regarding design tooling and (closed loop) quality assurance is highlighted.

3.2 Energy and Resource Efficient Manufacturing

Dr. Ing. Karel Kellens (KU Leuven, Belgium)

Taking into account the expected growth of the world's population and increasing welfare level in developing countries, the global energy and resource demand will increase significantly. Therefore, the environmental burden per unit produced should be strongly reduced. Manufacturing processes are responsible for a substantial part of the environmental impact of products but still poorly documented in terms of their environmental footprint. The lack of thorough analysis of manufacturing processes has as consequence that optimisation opportunities are often not recognised and that improved machine tool design in terms of ecological footprint has only been targeted for a few common processes. At the same time, a trend can be observed towards more energy intensive, advanced processing techniques.

This presentation provides a summary of the research performed within my PhD-research [1], focusing on the development of a pro-active approach to **document, analyse** and **improve** the **environmental impact** of **discrete part manufacturing processes**. A methodology for systematic documentation and analysis of manufacturing **unit process life cycle inventory** (UPLCI) has been developed [2] and applied on a wide range of discrete part manufacturing processes such as CO2-laser cutting, selective laser sintering [3] and electrical discharge machining. These case studies indicate that besides energy, also process consumables and solid waste streams often have significant contributions to the total environmental impact of manufacturing processes. In order to extend the number of analysed discrete part manufacturing processes, the CO2PE! Initiative [4] has been launched.

Furthermore, a framework for the development of **parametric process impact estimation models**, enabling the estimation of the environmental impact of the production phase of a product based on a limited set of product design features**,** has been proposed and illustrated for CO2-laser cutting and selective laser sintering [3] processes. An accurate prediction of the actual processing time is the biggest challenge here. Finally, a structured overview of generic as well as specific **environmental impact improvement measures** for discrete part manufacturing processes has been provided. Combining demonstrated available technological solutions for efficiency improvement, well-known engineering methods and intelligent process planning and control approaches, an environmental impact reduction of on average 50% seems realistic for discrete part manufacturing processes [5].

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3.3 Quality Control of mass-produced Proton Exchange Membrane Fuel Cells

Josef Mayr[1], Constantin Overlack[2], Konrad Wegener[2]
([1]inspire AG , [2]Institute for machine tools and manufacturing, ETH Zurich, Switzerland)

As 90% of the transportation sector is running on fossil fuels [1], leading companies of this sector are looking for alternatives. The disadvantage of battery based fully electrically driven vehicles is their limited range and the long recharging times. Due to their high efficiency and their high power- and energy density, Proton Exchange Membrane Fuel Cells (PEMFC) are one of the most promising technologies when it comes to alternatives for fossil fuels in the transportation sector.

The general production procedure of a PEMFC stack is given in Figure 1. Usually the single components of the stack are produced by specialised companies and are then assembled, packaged and braced, by an assembly company or an Original Equipment Manufacturer (OEM). As many PEMFC components are still manufactured in very small numbers and the manufacturing processes often involve a great amount of manual labour, the implementation of effective quality control (QC) is difficult. Defective or malfunctioning components are in many cases identified not before the entire PEMFC stack is fully assembled. This underlines that one of the greatest inefficiencies of the production process of a PEMFC stacks, hindering an economical mass production, is the lack of quality control [2].

To overcome this inefficiency, a quality control plan (QC plan) is developed. The plan explains different methods for inspection, how these techniques have to be applied and what the controlled variables are. It differentiates three levels of inspection: the component level, the single cell level, and the PEMFC stack level. Testing and QC starts on the component level. The key components, where testing is absolutely necessary, are: the Membrane Electrode Assembly (MEA), including its sub-components the Gas Diffusion Layer (GDL), the Membrane and the Catalyst layer, and the bipolar plates. An abridgement of the QC plan for the MEA is given in Table 1. The production speed for 152 mm/s was identified as a good entry speed for early stages of mass production and confirmed by companies in the field of PEMFC component production.

The research work shows proper methods for quality control during the whole production chain of PEMFC stacks. As not all components allow an in-line QC, the process capability of these production steps have to be in a range, that random sample inspection methods can be applied. For example the geometrical dimensions of bipolar plates have to be measured with coordinate measuring machines (CMM). Here further research is necessary to find a sensor system that allows in combination with an intelligent process data processing an in-process measurement. The QC plan shows that with today's production and inspection methods the 8 to 24 hour long End-of-Line test, including the humidification process and run-in of the PEMFC stack, cannot be eliminated or reduced. The research reveal the possibility of shortening the End-of-Line Test by implementing a not interrupted production, starting at the single components, all the way to the finished PEMFC stack. Due to uncertainties in the stack assembly, characteristic parameters of single cells and components within tolerance are only necessary condition for stack efficiency and thus cannot be used to predict stack efficiency, which makes end-of-line testing indispensable.

References

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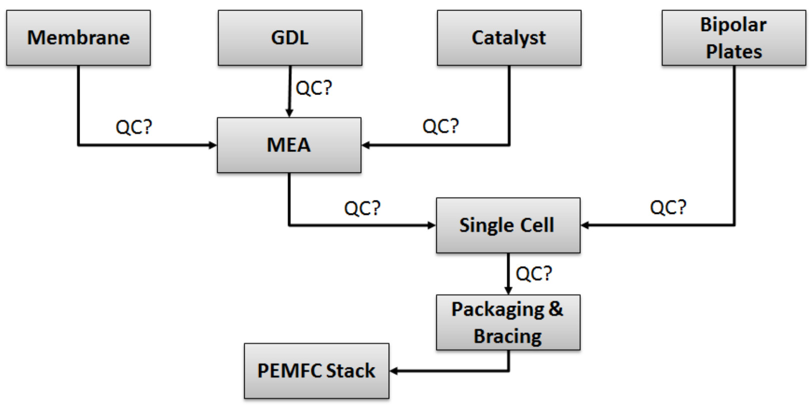

Figure 1: General Production Scheme of a PEMFC Stack

Table 1: Abridgement of the quality control plan: MEA and its components

Components	Method	In-Line/ Random Sampling	Production Speed	Defects	Defect Resolution
MEA	IR/DC through-plane	In-Line	>152 mm/s	Low resistivity, penetration, pinholes	>0.01cm
Membrane	Optical Reflectometry	In-Line	>152 mm/s	Thickness, holes, cuts	10-100µm depending on PEM size
CCM/GDL	IR/DC in-plane	In-Line	>152 mm/s	Indirect Pt.-loading, pinholes,	>0.01cm

				cuts, vacancies	
CCS	IR/Reactive Flow Through	In-Line	>152 mm/s	Direct Pt.-loading, pinholes, cuts, vacancies	>0.01cm

3.4 Optimisation module of Advanced Platform for Manufacturing Engineering and Product Lifecycle Management (amePLM)

Olga Battaïa (Ecole Nationale Supérieure des Mines, Saint-Etienne, France)

Project amePLM is a FoF-ICT-2011.7.4 Collaborative Project 285171 co-funded by the European Commission within the Seventh Framework Programme (2007–2013). The objective of the project is to engineer an ontology that serves as an interoperable model and integrating element for an open engineering system to be developed: the amePLM platform. This open engineering platform is based on existing tools and libraries, by special consideration of open-source software, assisting in product, process and manufacturing development, functional analysis, virtual testing and optimization based on heuristic methods and simulation that operate on knowledge represented by information, which is structured by means of an ontology.

The optimization module is a part of Work Package 4 – Engineering modules. The objectives of this work package are to research and develop specific modules to support engineering activities, including simulation and optimization modules, decision support modules and user-interfaces. The modules will be "docked" on the engineering platform with the ontology-based models as integrating elements serving as "one interface".

The optimization support module includes the optimization models and methods developed for the design and optimization of manufacturing lines in order to operate the production of the product in development at competitive cost and time.

The first pilot case deals with the design and the cost optimization of mixed-model assembly lines in automotive industry. These lines are paced and manufacture different types of products. A set of assembly stations in the main station is linked to a set of sub-assembly stations. Each sub-assembly station is associated with a unique assembly station. An assembly station may have several sub-assembly stations associated with it.

In each station, a group of identical workers perform some assembly tasks in predetermined sequences. Products enter the line in a given sequence one after another, and each product visits assembly stations in the same order. At the same station, the same tasks are performed sequentially for any product.

Each task requires a minimum amount of workers but also has an upper bound on the number of workers. If a worker is assigned to a task, he/she is fully occupied by this task from its start time till completion. After having completed a task, a worker can switch between stations. The switching time is assumed to be zero. The processing time of a task depends on the number of workers assigned to this task and the product type. The optimisation problem is to determine an assignment of workers to tasks such that the total number of workers is minimized and the line takt time is not exceeded.

Findings

A mathematical model was developed for the considered problem. It was proven to be NP-hard in the strong sense. As a consequence, eight constructive heuristics were suggested. Computer experiments showed the efficiency of the proposed heuristics, both in terms of solution quality and computational time.

3.5 Simulating Machining Processes Using Geometrical and Physically Based Models

Petra Kersting (TU Dortmund University, Germany)

In order to optimize machining processes without conducting time- and cost-consuming experiments, there is an increasing demand for process-simulation systems. At the Institute of Machining Technology (ISF), a simulation system is being developed which utilizes a geometric description of the material removal process and different physically based models for predicting, e.g., thermal effects, chatter, or the resulting surface structures. In this presentation, the applicability of these modelling techniques to simulate machining processes with geometrically defined and undefined cutting edges will be discussed.

3.6 System-level design supports with modeling and simulation techniques

Hitoshi Komoto

In designing complex engineered systems,various types of information about consumer surveys, experiments, simulations is shared among designers, engineers, and even managers. In this presentation, The author presents a tool, with which the participants of design workshop or design review can define information regarding parameters and requirements of a design object and their relations. The tool is equipped with various graph search algorithms that help analyze and visualize the parameter relations from various perspectives.Furthermore, in the presentation, the author presents a novel design support system using the result of system simulation, which is derived from an equation system implicitly defined in a Modelica model.

3.7 Phenomenographical characterization of the key concept of Flexibility in the domain of manufacturing engineering

Antonio Maffei (KTH, Sweden)

This work introduces a phenomenographic analysis of the concept of flexibility in the domain of production science. Flexibility is a cornerstone in the education of industrial and production engineers, however it still appears as a broadly and even inconsistently defined construct. In order to clarify what is, or should be, learnt this work analyzes first the established literature to extract a "working" characterization of the flexibility concept. The resulting understanding is then used to represent the experts' perception of the topic which in turn is used as ideal level of understanding that a student should achieve her/himself when studying such a concept.

The second phase of the work aims at disclosing and classifying the multifaceted perceptions of flexibility that two different classes of industrial engineering students have after two courses in which the focal concept of manufacturing flexibility has been presented using two different approaches. The research is based on a survey on the students. The collected data have consequently been structured in a finite set of clusters according of: (1) the level of understanding of the key concept (2) the nature of the shown knowledge. The classification is then the basis for defining an epistemological sound approach to develop suitable teaching and learning activities to ensure optimal acquisition of the concept of flexibility

3.8 Pushing the boundaries of polymer sintering

Candice Majewski

Additive Manufacturing (AM) is the umbrella term for a range of processes manufacturing parts, layer by layer, directly from a 3D Computer-aided design (CAD) model. In terms of polymer AM, Laser Sintering (LS) is widely regarded as one of the most promising processes, in terms of its mechanical properties (in some cases comparable with Injection Moulding) and the geometric complexity achievable.

However, the range of materials for LS is currently extremely restricted (mainly Nylon-based), and often prohibits the use of LS in otherwise suitable applications. Global manufacturers have recently begun to engage in the development of materials for this process, but are restricted by lack of knowledge of the LS process and its influencing factors.

The main focus of Dr Majewski's work is obtaining a deeper understanding of the characteristics required for a 'good' Laser Sintering material, in terms of chemical, physical and thermal properties.

To date this has been via experimental assessment of the effects of these properties, for example measurement of mechanical properties or micro-structural evaluations, combined with knowledge obtained from existing theoretical models (e.g. the Frenkel viscous sintering model). However, no model currently exists to predict the suitability of a material for LS, or the resultant mechanical properties, and this is the current focus of Dr Majewski's work.

3.9 Portable Machining Concept for Large Scale Part Manufacturing in Nuclear Industry: Robotic Milling

Taner Tunç

The Nuclear AMRC is part of the AMRC group, acting as the manufacturing research base for civil nuclear sector. The Nuclear AMRC helps UK companies win work in the civil nuclear sector – in new build, operations and decommissioning. The Nuclear AMRC leads manufacturing innovation and supports the development of suppliers. In this study, the activities carried to utilize portable machining concept, at the Nuclear AMRC is discussed through robotic milling application.

The use of Robotic milling in order to enable 'mobile manufacturing', is considered to be a more cost effective and portable alternative to traditional CNC machine tools. Thus, it is started to be used in the manufacture of large scale components designed in industries such as aerospace and nuclear energy. Robotic milling has many potential advantages but is also subject to a number of serious technical challenges. Robotic platforms used in mobile machining are notorious for their low dynamic rigidity, mode coupling and position dependent dynamic comparison to traditional CNC machine tools. In this study, the dynamics and stability of robotic machining are investigated with specific focus on the analysis of the system's dynamic and positional behaviour in milling, where a FANUC F200ib hexapod robotic machining platform is used. After identifying the sources of flexibilities, process stability models are applied in order to establish chatter free cutting conditions for improved productivity. In addition, the positional accuracy capability of the hexapod robot is also discussed to establish relationship between the dynamic flexibility and static flexibility.

3.10 Manufacturing of structured surfaces via grinding

Benjamin Kirsch, Jan C. Aurich (University of Kaiserslautern, Germany)

Surface structures are used to extend technical components life. Surface structures, also called functional surfaces, provide additional space for cooling lubricant and favour the generation of pressure in the lubrication film at low sliding speeds. As a consequence, friction in technical components is decreased, resulting in reduced wear. The manufacturing of such structures is nowadays generally done applying lithography, etching, laser techniques and high-precision machining.

In this research, the possibilities of applying grinding to produce structured surfaces is investigated. Grinding allows a much faster production of structured surfaces in several kinds of material to improve efficiency and sustainability of materials used in technical components. The structures manufactured are a composition of single grain scratches, arranged in deterministic patterns. Therefore, special grinding tools with grains arranged in a defined grain pattern are used. Besides the use of special tools, the kinematics of the grinding process (surface grinding) has to be known and controlled to be able to manufacture structured surfaces. This is achieved by describing the kinematics via analytical equations and by the development of a simulation tool based on these analytical equations.

Using a single grain pattern, the possible structures that can be manufactured are limited. However, the variation of the kinematics enables to manufacture a large variety using a single grain pattern: dense as well as open, simple and complex structures. Figure 1 gives some examples of possible structures that can be manufactured with the first prototype grinding wheel, also shown in the figure. The shape of the single scratches results from the shape of the respective active grains. To be more specific, the cross-section of a scratch is given by the shape of the active area of the grain.

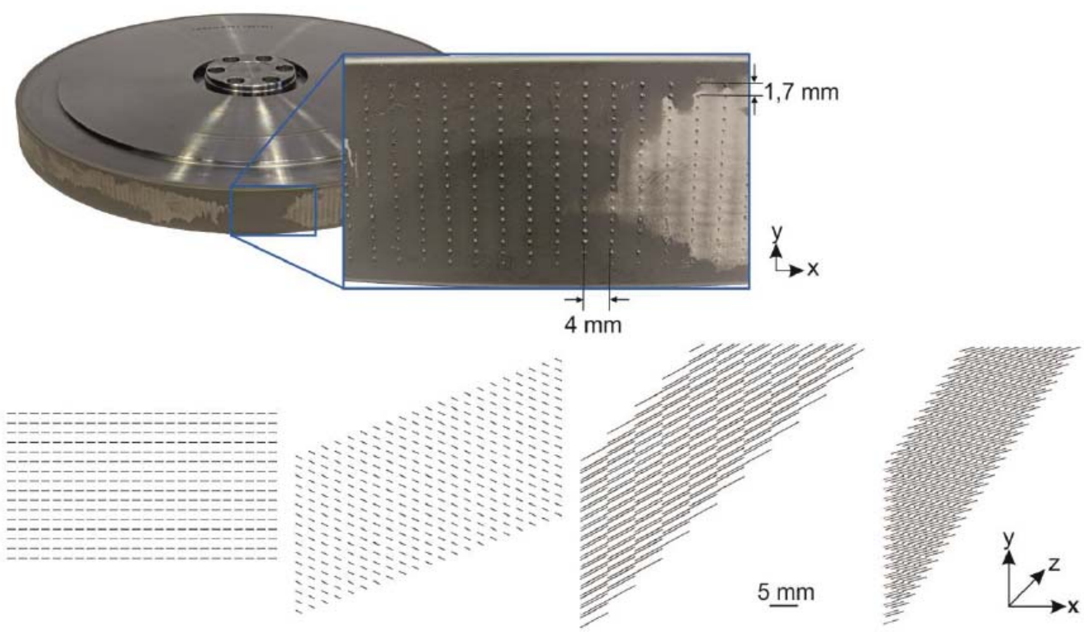

Figure 1: Prototype grinding wheel and some simulated sample structures

To evaluate the new approach, micro structures were ground in a low-alloyed steel of low hardness (200 HV 0.3). The structures were evaluated with regard to uniformity, length and width of the single scratches as well as burr formation. This was done using light microscopy and digital fringe projections systems. Figure 2 exemplarily shows two sample structures and their measurement. As can be seen, uniform structures can be manufactured. There are some blank spaces resulting from grain breakouts or placement errors from the wheel manufacturing. For large structured areas those can be expected to be negligible considering tribological performance. A current limitation is the burr formation. Burrs would result into increased friction of the sliding parts in use. Adequate deburring methods, such as polishing or etching, will be evaluated in future works.

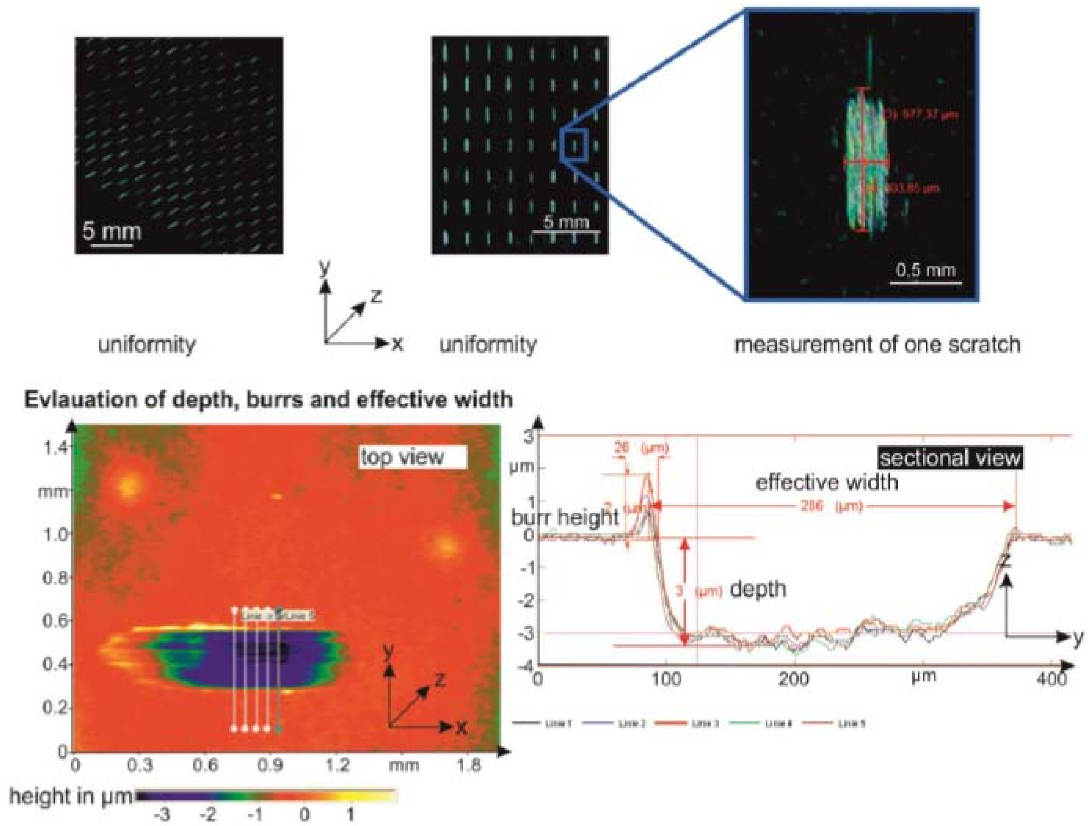

Figure 2: Example structures and measurement

The biggest advantage of the new approach is the short process time. For the two structures depicted in figure 2 with functional surfaces of 1,250 and 1,500 mm² respectively, process times of only 0.063 seconds were required. Competitive structuring processes such as laser techniques or high-precision machining require considerably higher process times. In addition, the new approach can be implemented in conventional grinding machines to be conducted directly after the last finishing process when machining sliding components, as this final step is commonly done by grinding.

RA Participants

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