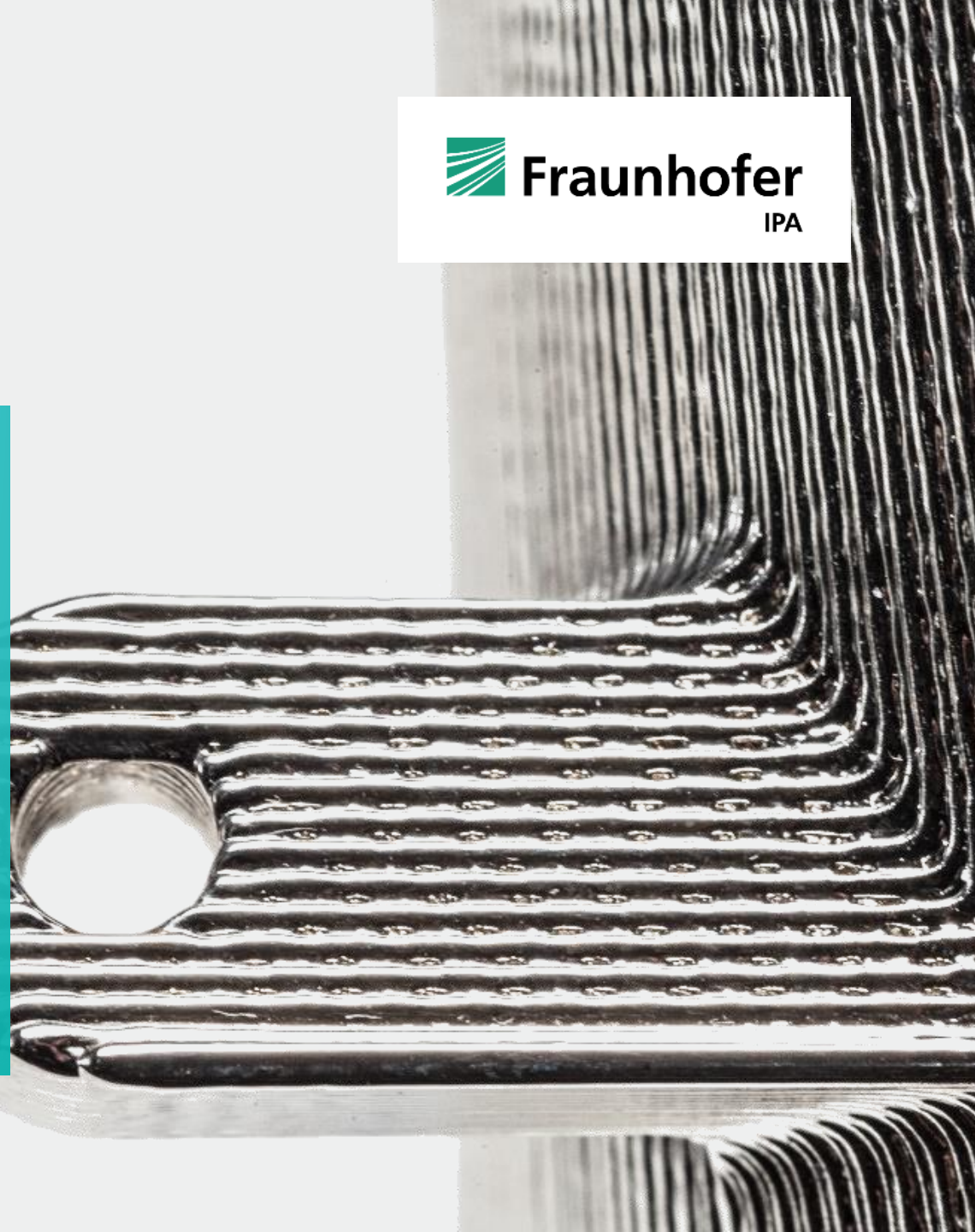
Fraunhofer IPA

DeburringEXPO Fachforum

Date: 10.10.2023

Effects of post-processing methods on the surface properties of additive manufactured plastic components



Fraunhofer-Gesellschaft

Research and create innovations

More than

30 000

employees

In 2021, the hiring rate for female scientists increased to 29 percent (overall, about 23 percent female scientific staff).

More than

75

institutes

2

patent applications per working day

90 %

of our institute directors have a department chair

They combine university research with applied research and development at Fraunhofer.

approx.

30

spin-offs per year

... over 500 since the year 2000. Approximately 80 percent are still on the market after ten years.

More than

7600

active patent families

Fraunhofer is an EU-wide leader in setting standards.

approx. **72.1 %** scientific, technical and administrative personnel

approx. **1.7 %** trainees

approx. **26.2 %** students

Fraunhofer is both an attractive employer and a career springboard.

2.5 billion

euros revenue per year from contract research

Demand from business and society guides growth.

Quelle: Fraunhofer-Gesellschaft

Fraunhofer IPA

Innovation driver with a scientific reputation since 1959

At a glance

- Over 1,000 projects with industrial customers each year
- Approx. 1,200 employees at 9 locations (headquarter: Stuttgart)

- 23 patents granted (10 in Germany, 13 internationally)
- 855 publications

- Key figures in 2022 in € million [1)]
  - Total budget: 90
  - Operating budget: 82 [2)]
  - Investment budget: 8
  - Industrial revenues: 24

1) All figures include Fraunhofer Austria Research GmbH, Vienna, Production and Logistics Management
2) Adjusted operating budget: increased by cost-reducing internal cost allocations with IPA value creation of around €3 million

Technical equipment and laboratories

In tune with current needs

Networked Production
- Application Center Industrie 4.0
- Future Work Lab
- Factory planning and production laboratory

Resource-efficient Production
- Digital Green Factory Lab
- DC-Lab
- Lab for smart compressed air systems

Intelligent Automation and Clean Manufacturing
- Cleanrooms
- Robotics Testing Facility
- Vision Lab

Medical Engineering and Biotechnology
- Biomanufacturing laboratory
- Intervention room
- nICLAS Lab of the future
- Virtual Orthopedic Lab

Surface Engineering and Materials Technology
- Electroplating laboratory
- Coating technology center
- Laser welding
- Dispersion technology center
- Particle technology center

Manufacturing and Process Engineering
- Labs for cutting, joining and sawing
- Labs for additive manufacturing

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Polymerbased Additive Manufacturing at Fraunhofer IPA

Department Additive Production

OUR VISION: EMPOWERING ADDITIVE MANUFACTURING FOR PROFESSIONAL APPLICATIONS!

Cross-industry | Cross-process | Cross-material | Focus on entire process chain

ADDITIVE PROCESSES **HYBRID PROCESSES** **SYSTEMS ENGINEERING** **INDUSTRIALIZATION**

Additive Prozesse

Polymerbasierte Additive Fertigung am Fraunhofer IPA

Forschungsfelder

- Fokus auf polymerbasierte Materialsysteme
  - Photopolymere
  - Thermoplaste
  - Gefüllte Materialien:
    metallisch | keramisch | faserverstärkt
- Prozesse:
  - MJ
  - SLA & DLP
  - SLS
  - FLM
  - AKF
  - SAF

Leistungsangebot

- Vorbereitung
  - Anwendungsspezifische Auswahl von Verfahren
  - Design und Datenaufbereitung für AM Prozesse
- Prozess
  - Verarbeitung von anwendungsspezifischen (Sonder-) Materialien
  - Verfahrensentwicklung und –optimierung
- Analyse
  - Analyse von Ausgangsmaterialien
  - Analyse gedruckter Bauteile

Hybrid Processes

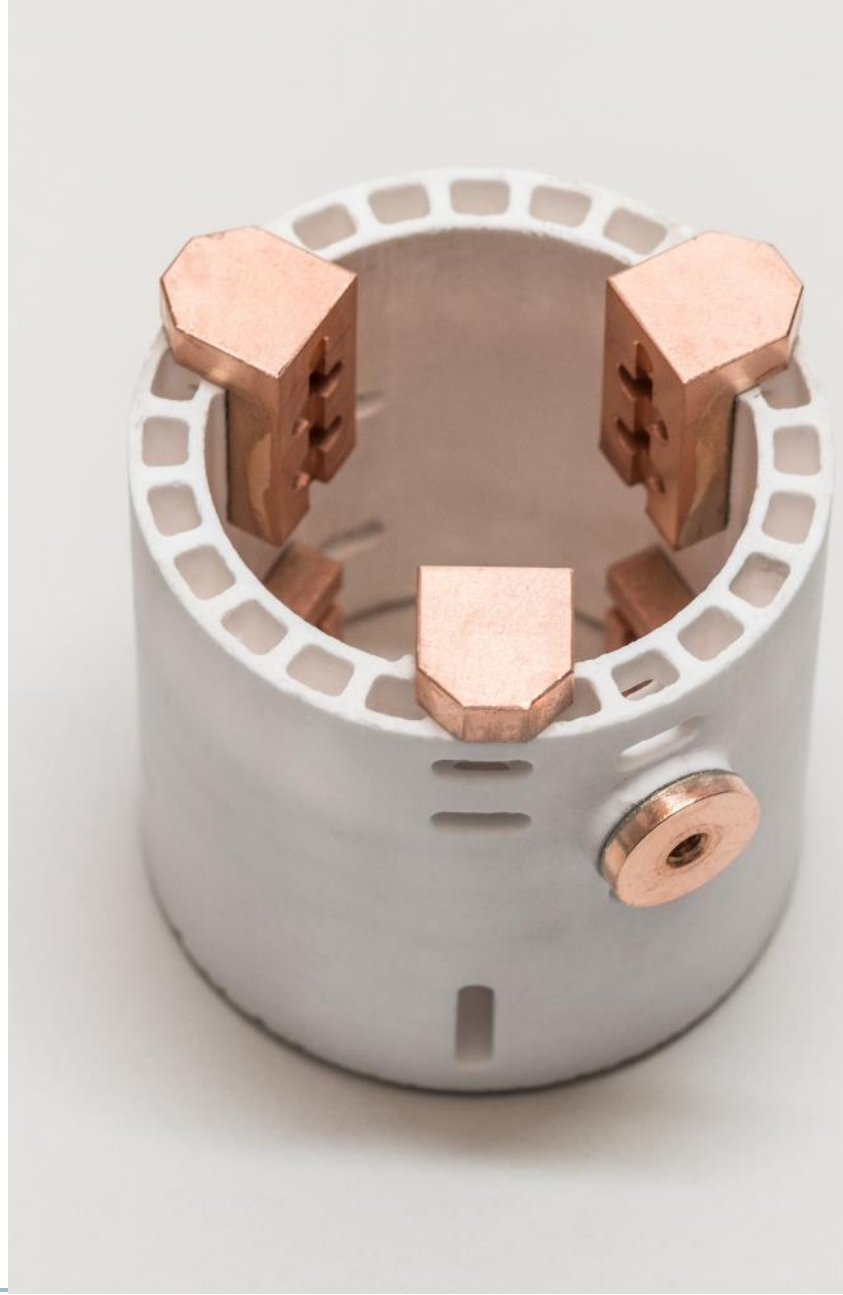
Polymerbased Additive Manufacturing at Fraunhofer IPA

Research Focus

- Functional integration
  - Enhanced functional integration and improved parts properties based on combined processes
- Combination of additive and conventional processes
  - Inline Integration
  - Sequential process chains
  - Integration of dicrecte components in printing process

Service Portfolio

- Screening
  - Exploitation of new fields of applications for AM parts based on enhanced parts functionality
- Process Development
  - Application-specific development of combined process chains
  - Selection and application of complementary processes
- Qualification
  - Test und Qualifikation von Bauteilen und Funktionsbaugruppen



Systems engineering

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Research Focus

- Design of Lab-Equipment
- Implementation of processes at lab scale
- Development of tailored machine equipment and peripheral systems
- Integration of AM-processes in production environments at control level
- Adaption and integration of commerical systems

Service Portfolio

- Concept development
  - Requirements analysis, conecpt and design for process modules and machine equipment
  - Support in developping specification sheets
- Hardware
  - Development of AM Hardware including control systems
  - Industrial inkjet-printing systems including peripheral processes
  - Development of lab-scale systems
- Implementation
  - Setup and optimization of process equipment

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Industrialization

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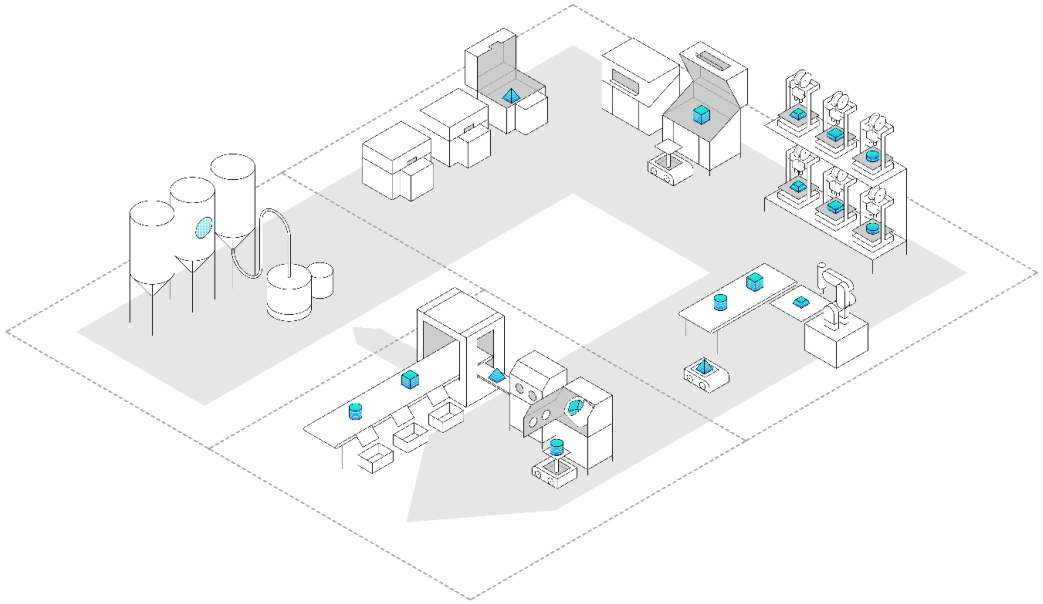
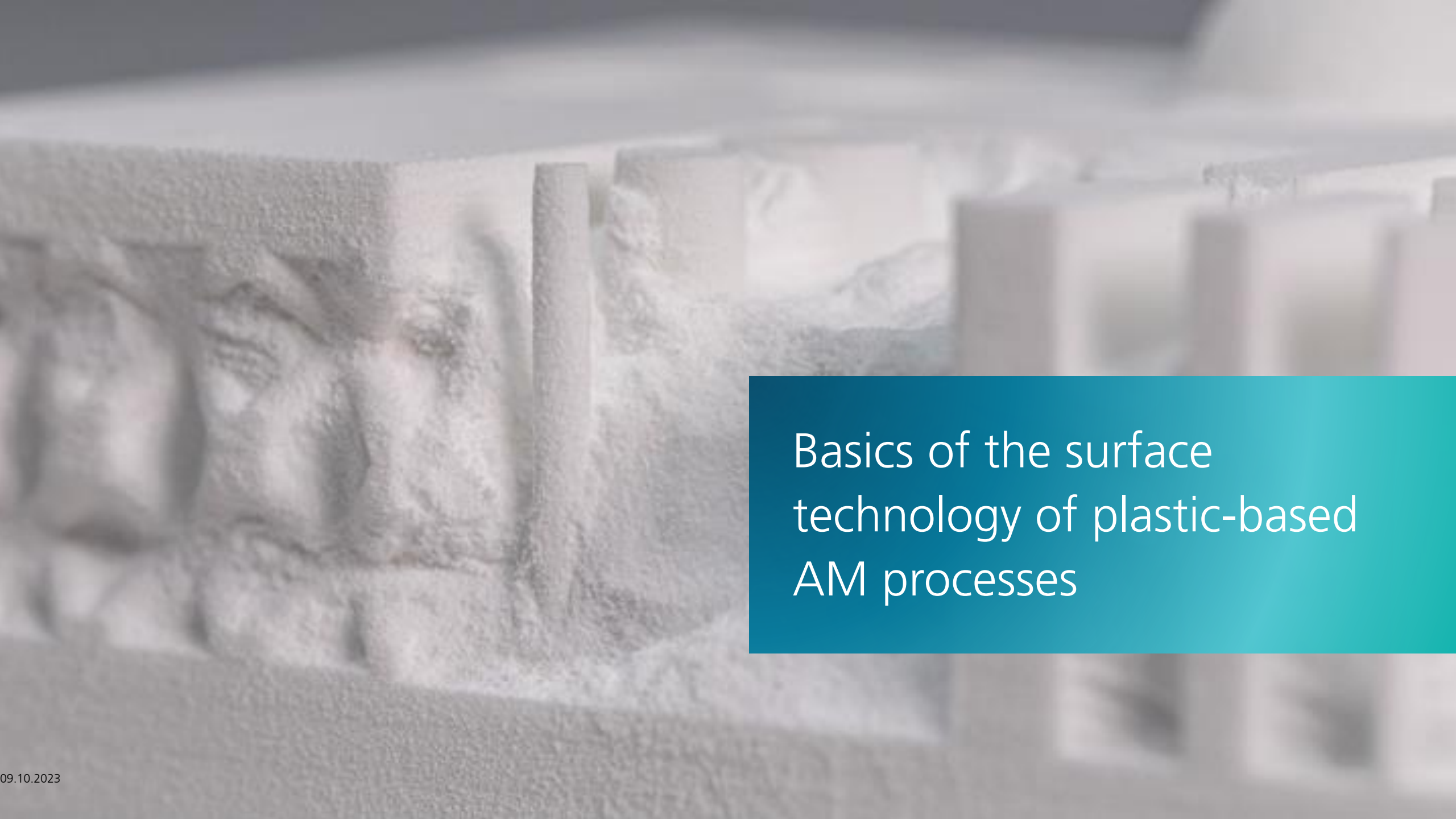
AM-production in industrial environments

- Consideration of AM-based process chains in industrial environments
- Development of pre- and postprocessing steps and parts handling
- Interfaces to integrate AM-processes in digitised production environments
- Development of business models for AM
- Development of quality assurance methods

Use of AM in industrial environments

- Parts selection and -optimization
- Design for AM
- Business model development
- Consulting on AM processes and process chains
- Consulting on health and safety at work



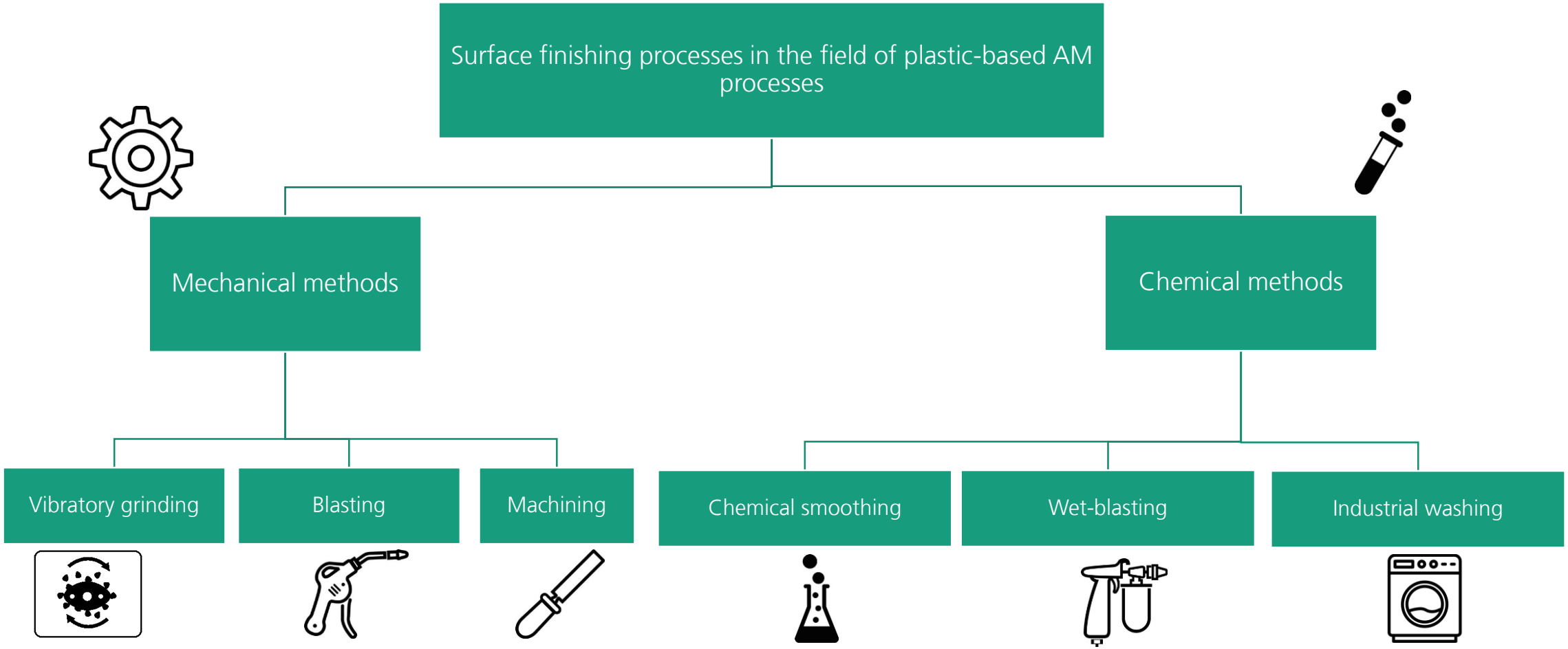


Basics of the surface technology of plastic-based AM processes

09.10.2023

Basics Additive Manufacturing

Overview of surface finishing methods



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Basics Additive Manufacturing

Chemical methods

Chemical smoothing

How it works:

A chemical agent (solvent) is used to etch the surface of components and thus remove fine peaks, which increases the roughness of the surface.

Achievable roughness using the example of MJF: Ra > 1 µm [Source: apc-tec]

Advantages:

- Geometry independent
- Density against liquids and gases
- Very good surface finish compared to injection moulding
- Improvement of the mechanical properties

Equipment for chemical smoothing : DYEMANSION]

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Mechanical methods

Vibratory grinding

How it works:

Workpieces as well as grinding and polishing tools are placed together with a solution in a container and through oscillating or rotating movement of the container, a relative movement is generated between the workpiece and the processing medium, thus causing material removal.

Achievable roughness using the example of MJF : Ra < 1,5µm [Source : Dörfler & Schmidt]

Advantages:

- Remove or smooth layer traces
- Ease of use
- Good for serial application

SLS - component in vibratory grinding machine [Source: apc-tec GmbH]

Basics Additive Manufacturing

Mechanical methods

Blasting

How it works:

During blasting, the abrasive is accelerated by means of a medium, e.g. air or water. This accelerated jet is brought to impact on the workpiece to be processed (blasting material). Three steel effects are distinguished on the surface: deformation, hardening and abrasion.

Achievable roughness using the example of MJF : Ra < 2,5µm [Source : Dörfler & Schmidt]

Advantages:

- Process independent of parts geometry
- Manual or automated processes
- Low removal of material

Blast basket in a blast machine [Source : MST-reutlingen]

Experiments at the Fraunhofer IPA and MST Microstahltechnik GmbH

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Experiments
Goal

Goal:

- Significant results on the effect of blasting processes on the parts surfaces of additively manufactured parts made of plastics
- Reduction of the influence of the operator resulting in better comparability
- Comparison between operator and automation

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Experimental design and execution

Experimental design and execution

Approach

Experimental setup

Parts by fixture Blasting

- Defined speed
- Defined distance between blasting gun and workpiece
- Better comparability between the parameters and the results

Selected blast parameters:

Rotation speed	0,5 $^{1}/_{min}$
Distance from blasting gun	25 – 40 mm
Offset of the blasting paths	10 mm

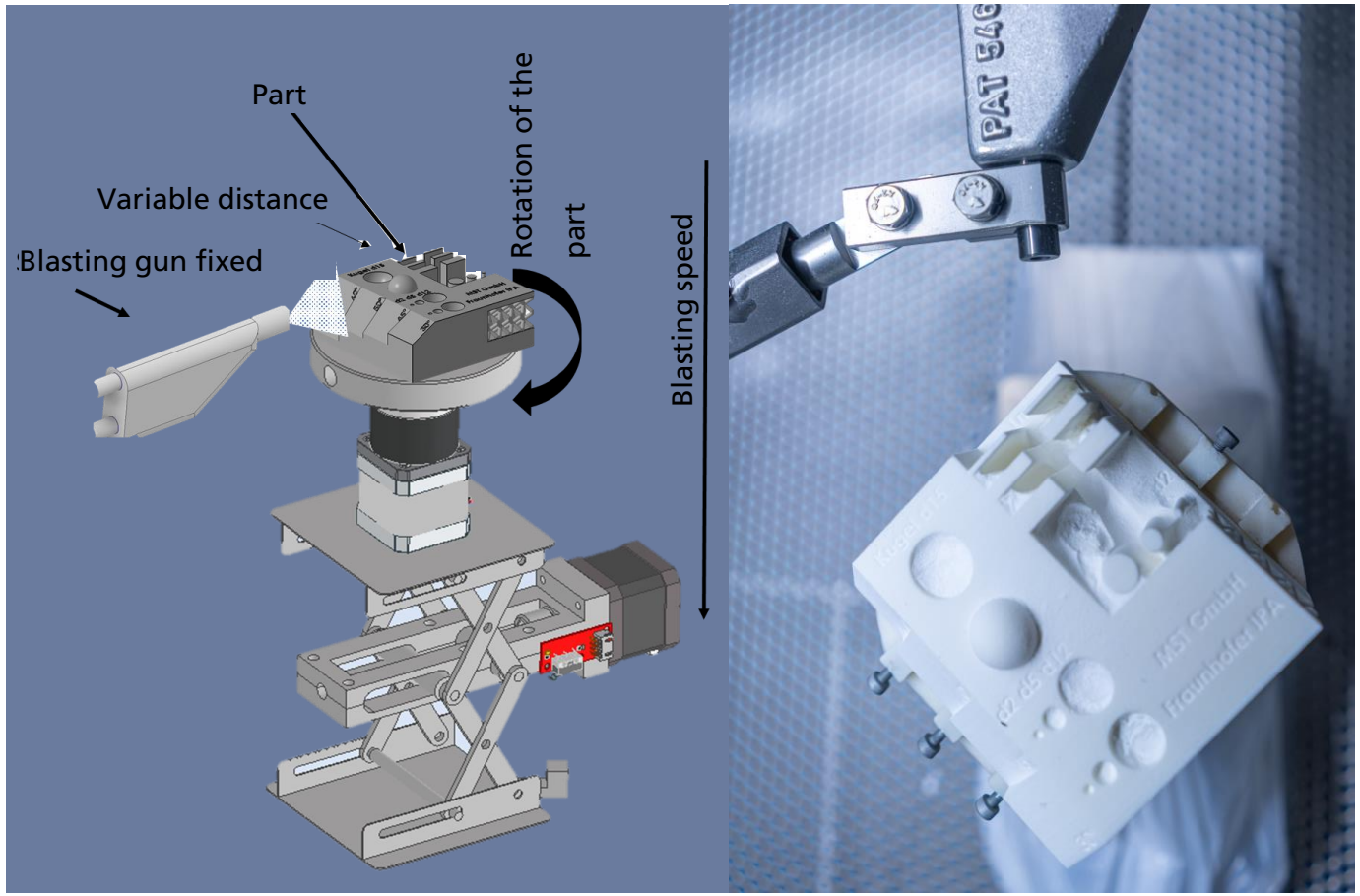


Figure left shows experimental set-up for blasting, figure right shows self-built set-up in blasting cabin

Experimental design and execution

Experimental procedure

First clamping of the sample part

Second clamping of the sample part

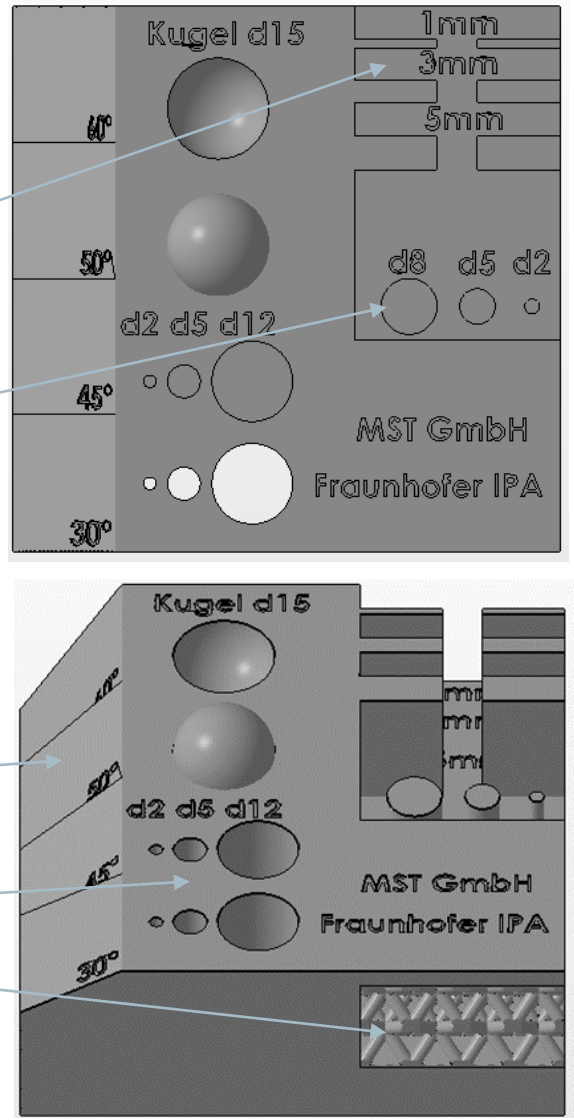
Experimental design and execution

Sample part and criteria for part evaluation

Evaluation criteria assigned to the geometries of the sample part

Damage

- Fracture of thin structures
  - Wall 1 mm, 2 mm, 5 mm
  - Diameter 2 mm, 5 mm, 8 mm
- Surface roughness
  - Surfaces vs. angular surfaces
    - Top side, layer direction to 30°, 45°, 50°, 60°
- Complex structures and holes
  - Qualitative evaluation of cleaning effects



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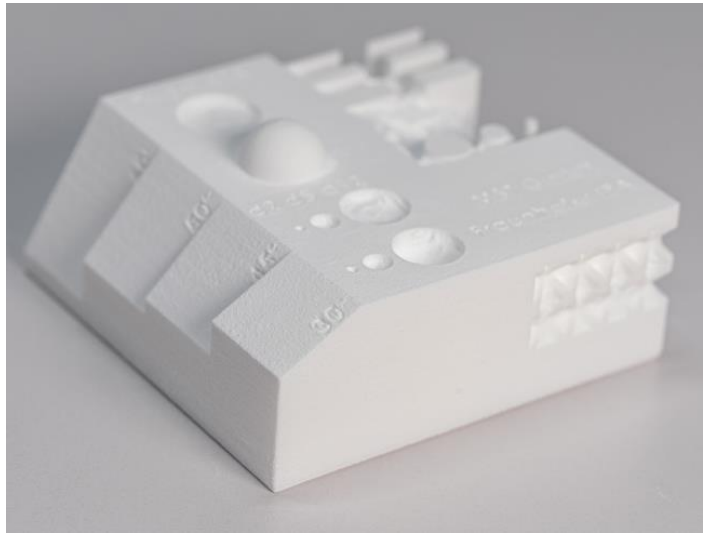
Experimental design and execution

Planned printing materials, manufacturing processes and blasting media

PA12 – Sampel part (SLS)

blasting media:

- Broken glass
- Plastic granulate
- Ceramics

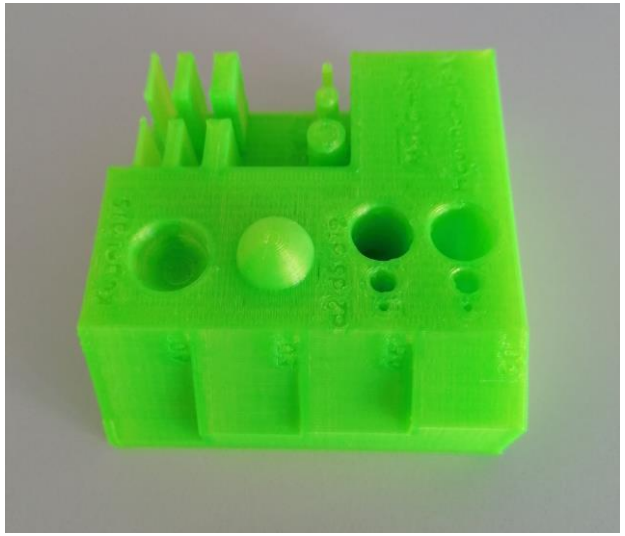


Sample part made of PA12 printed by SLS

PLA – Sampel part (FLM)

blasting media:

- Broken glass
- Plastic granulate
- Normal corundum

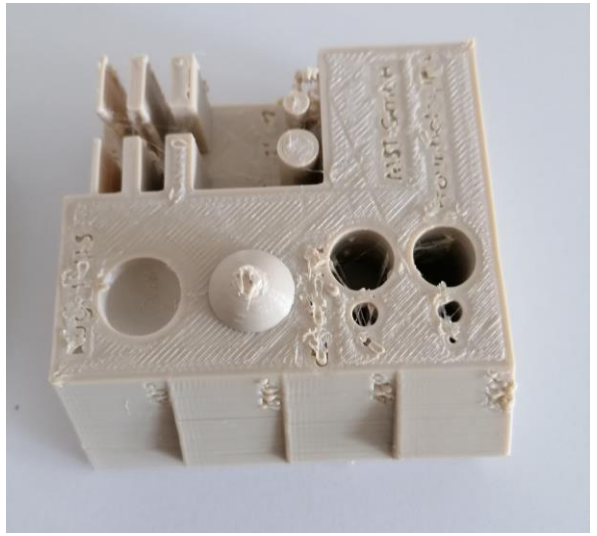


Sample part made of PLA printed by FLM

PEEK – Sampel part (FLM)

blasting media:

- Broken glass
- high-grade corundum
- Ceramics



Sample part made of PEEK printed by FLM

Experimental design and execution

Experiment evaluation

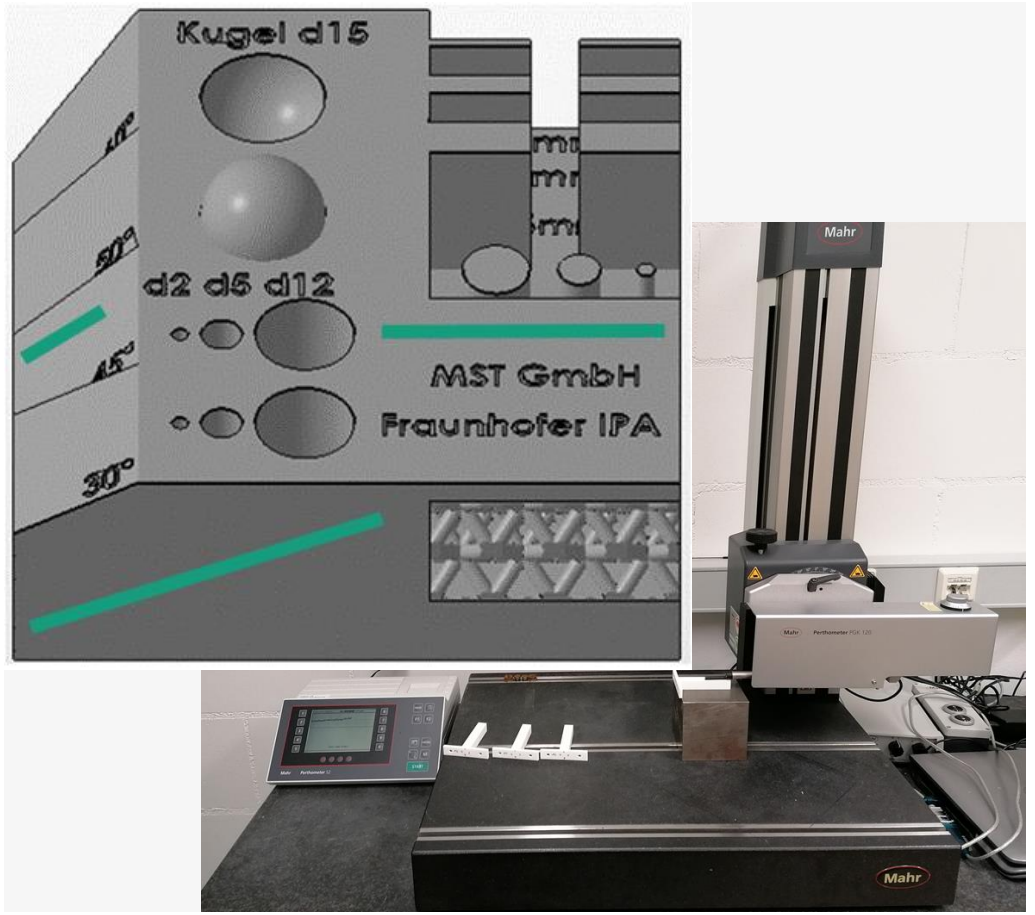
Quantitative test

Measuring the roughness by means of a tactile roughness tester

- Measuring the different slopes
- Measure surface and one side

Measuring position for roughness measurement

The three green lines represent the measuring section for the roughness measurement



Sample part with measuring sections and tactile roughness measuring device from the company Mahle

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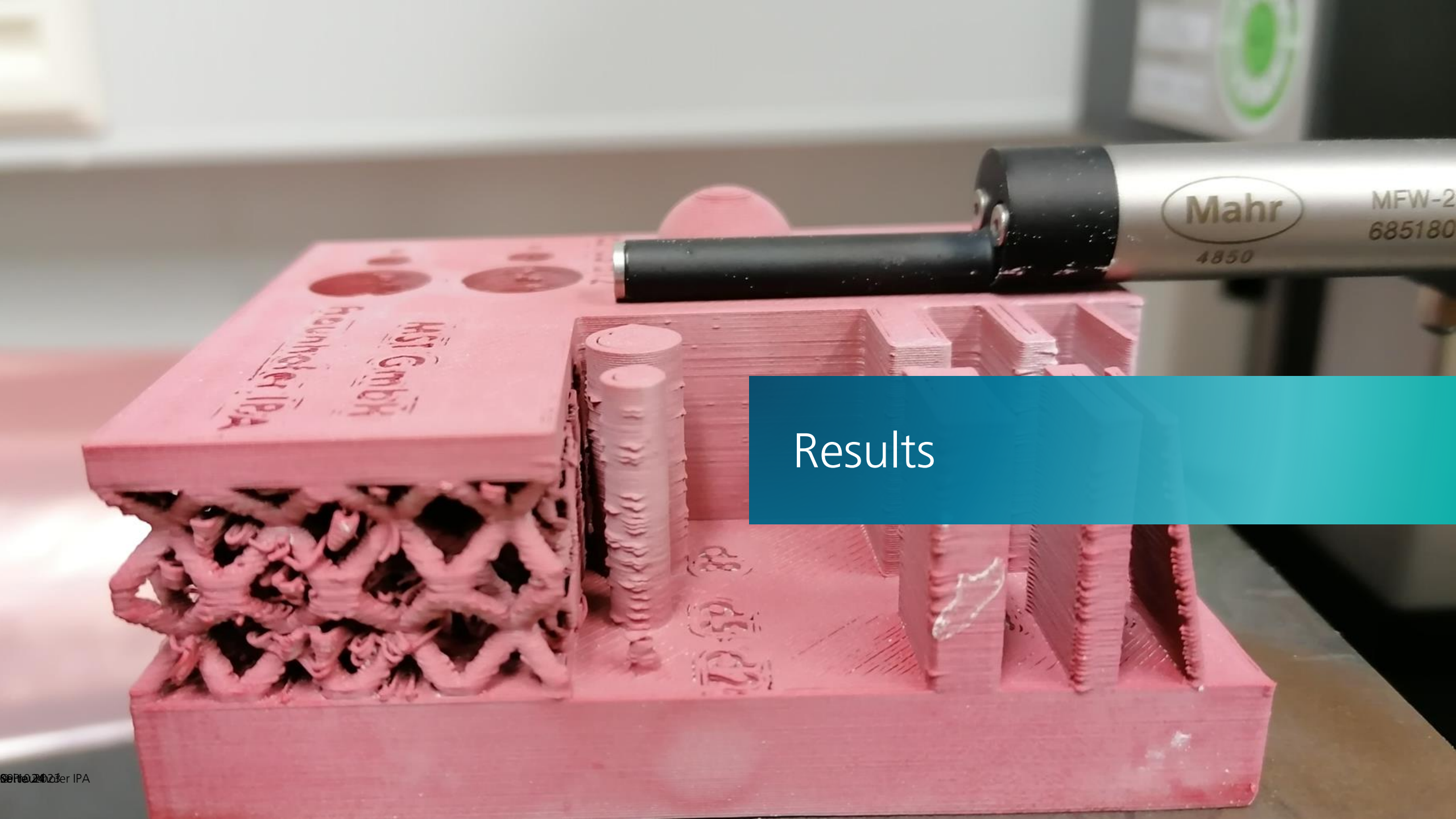
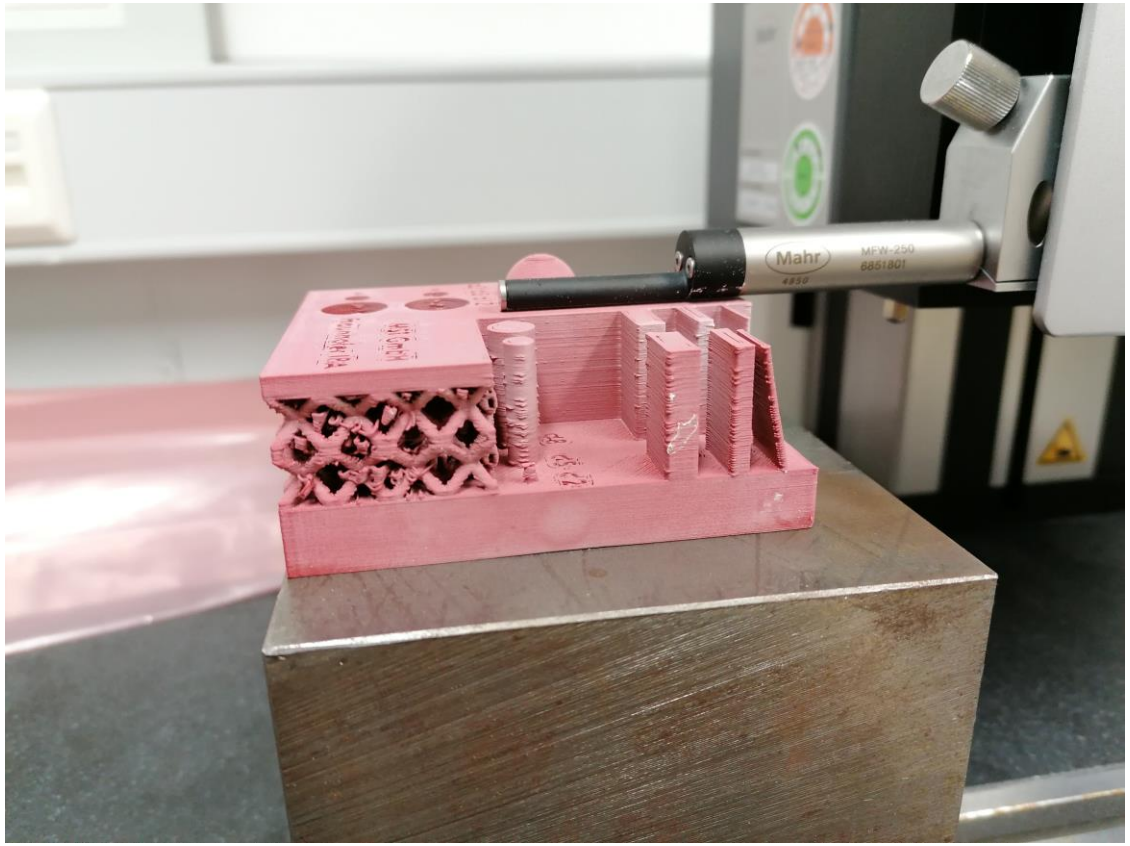


Results

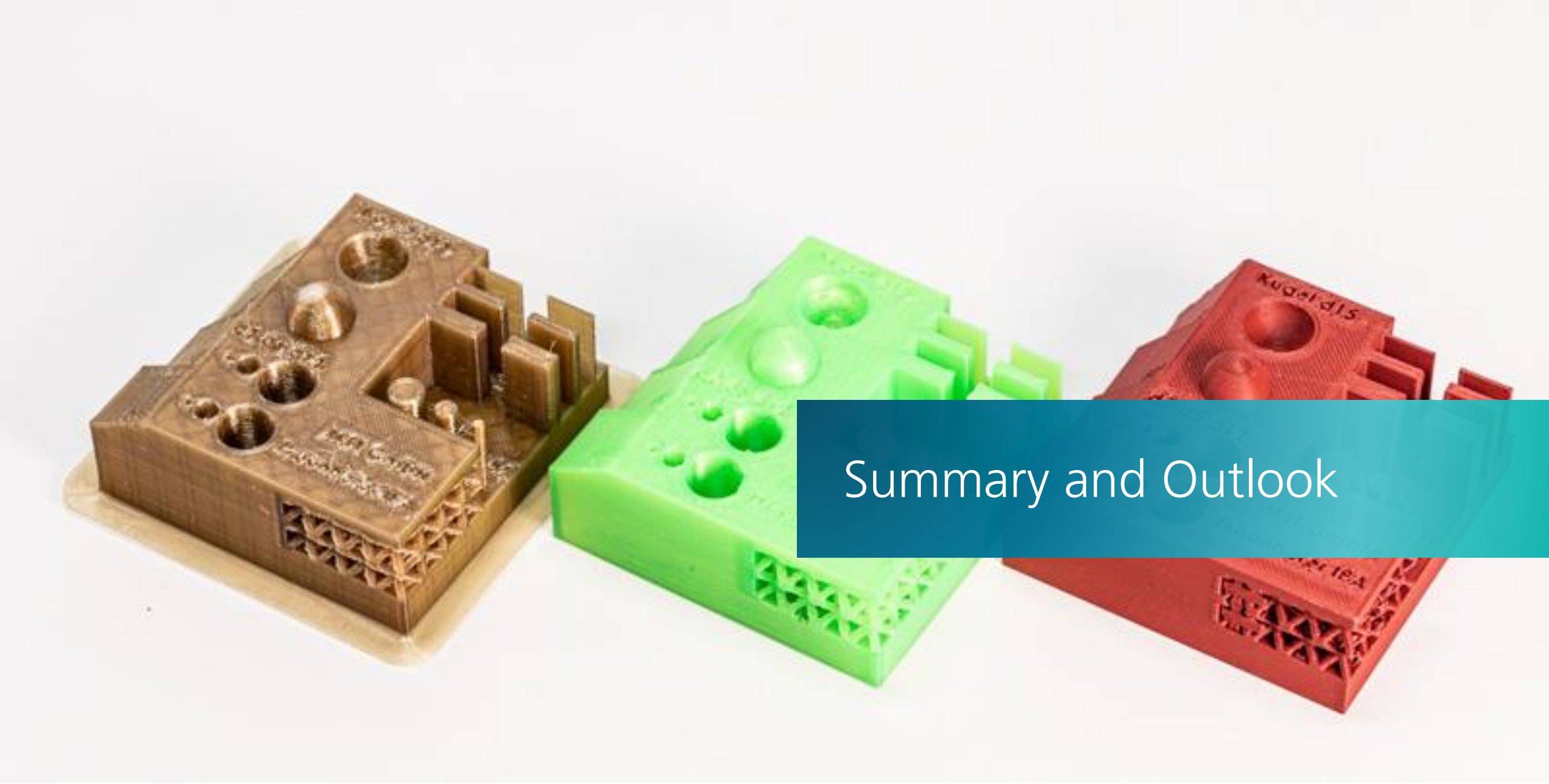
Results
Summary

Results of the roughness measurement

- For PLA, the largest improvement of **32.8 %** was achieved with broken glass in the manual blasting process
- For PEEK, the largest improvement of **61.8 %** was achieved with high-grade corundum in the automatic blasting process
- For PA12, the greatest improvement of **52.2 %** was achieved with plastic granules and broken glass. Both are abrasive blasting media
- A greater improvement was achieved with the **automatic blasting process** compared to manual blasting.
- **Damage** was found in thin structures with PLA



Measuring the roughness of a sample part made from PLA



Summary and Outlook

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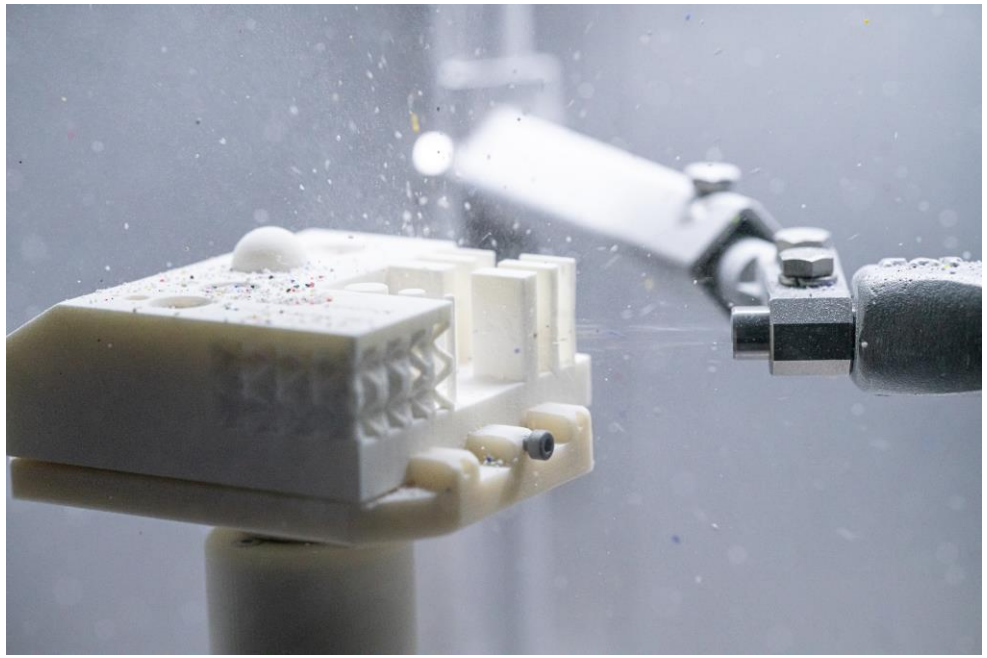
Summary
Conclusion and outlook

Conclusion

- In the area of the blasting process of AF-manufactured parts, the **surface characteristics achieved** are usually **not yet known**, which makes it difficult to compare them with others at present.
- The **surface roughness** already showed **greater differences** depending on the blasting medium.
- Depending on the application, it may be worthwhile to use a **blasting medium and process parameters specially adapted to the part** in order to design an efficient process.
- The **automatic blasting process** showed a **more consistent and smoother surface** than the manual blasting process in the quantitative evaluation of roughness.

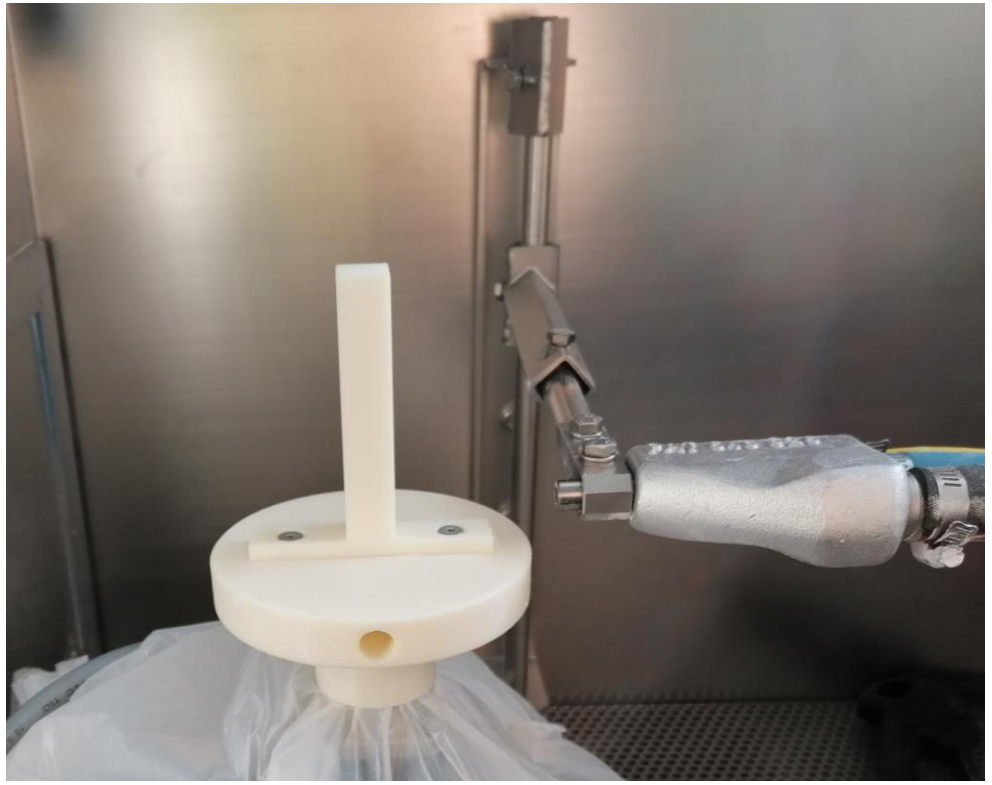


Sample part blasting with plastic blasting medium

Summary
Conclusion and outlook

Outlook

- **Parameter variation** in the blasting process e.g. variation of the blasting pressure
- **Combination of different blasting media**, e.g. broken glass with fine glass beads, so that large areas can be blasted efficiently but also, for example, fine bores can be processed.
- **Checking the results** on e.g. drum blasting system which is the standard in small series application
- Furthermore, a **formalised approach** for better comparison at the Fraunhofer was further developed on the basis of the tests.



Structure of the formalised approach with test pieces used

Thank you for your attention!

Contact

Mark Becker
Department Additive Manufacturing
Phone +49 711 970-1790
Mark.becker@ipa.fraunhofer.de

Fraunhofer IPA
Nobelstraße 12
70569 Stuttgart
Germany
www.ipa.fraunhofer.de

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