Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

25.10.2022

Additive Alliance – IAPT News

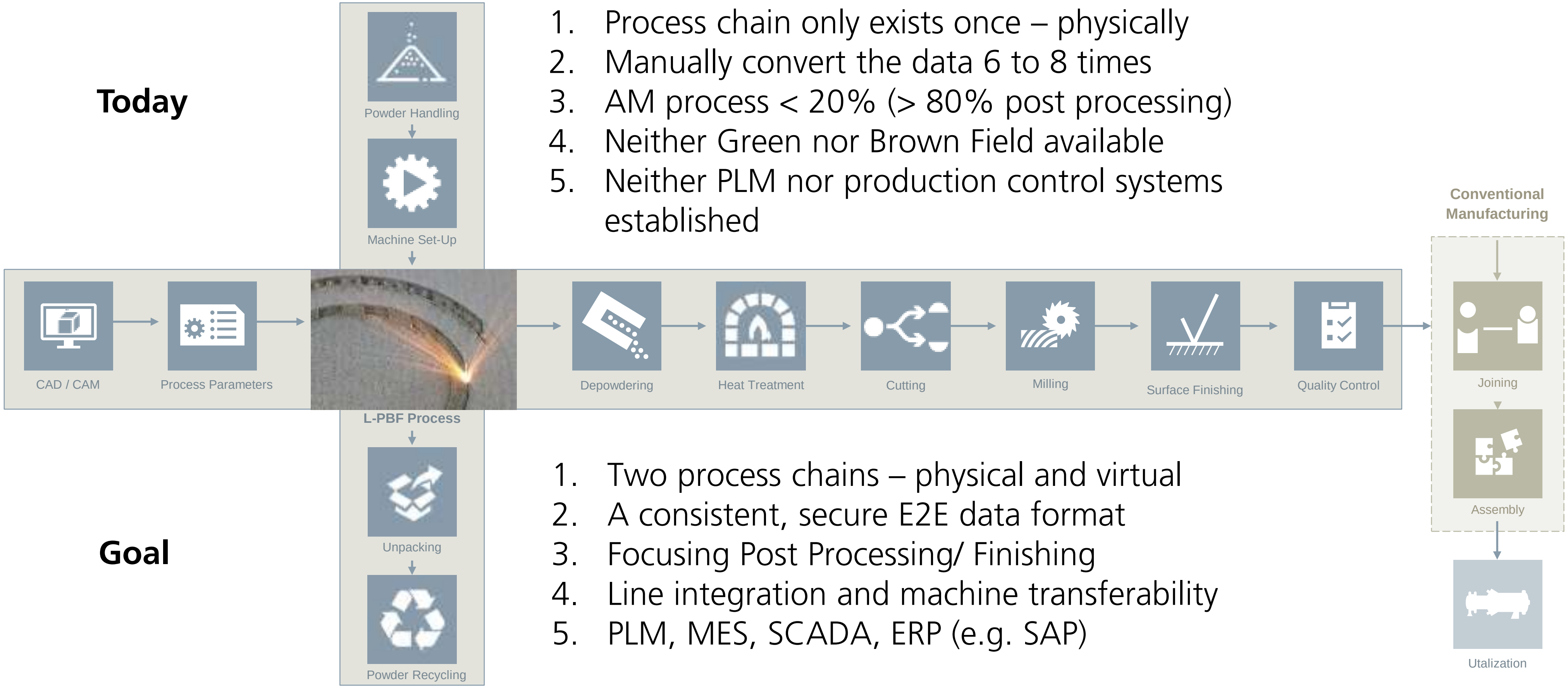
Frank Beckmann

End-2-End Process Chain

Challenges of & Solution approaches for industrialization

Today

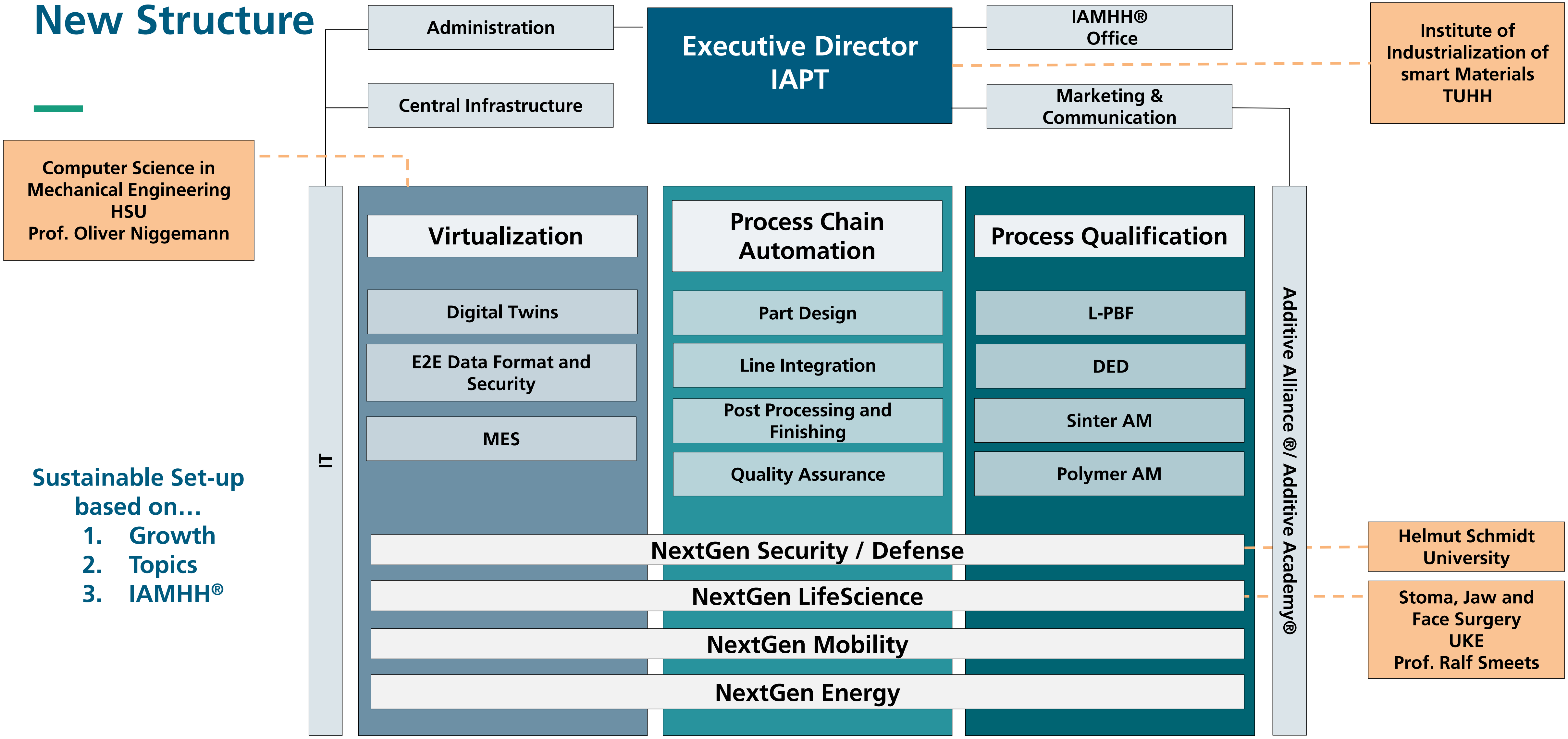
1. Process chain only exists once – physically
2. Manually convert the data 6 to 8 times
3. AM process < 20% (> 80% post processing)
4. Neither Green nor Brown Field available
5. Neither PLM nor production control systems established



Goal

1. Two process chains – physical and virtual
2. A consistent, secure E2E data format
3. Focusing Post Processing/ Finishing
4. Line integration and machine transferability
5. PLM, MES, SCADA, ERP (e.g. SAP)

New Structure



Sustainable Set-up based on…

1. Growth
2. Topics
3. IAMHH®

Fraunhofer IAPT

Institute for Industrialization of Smart Materials (TUHH)

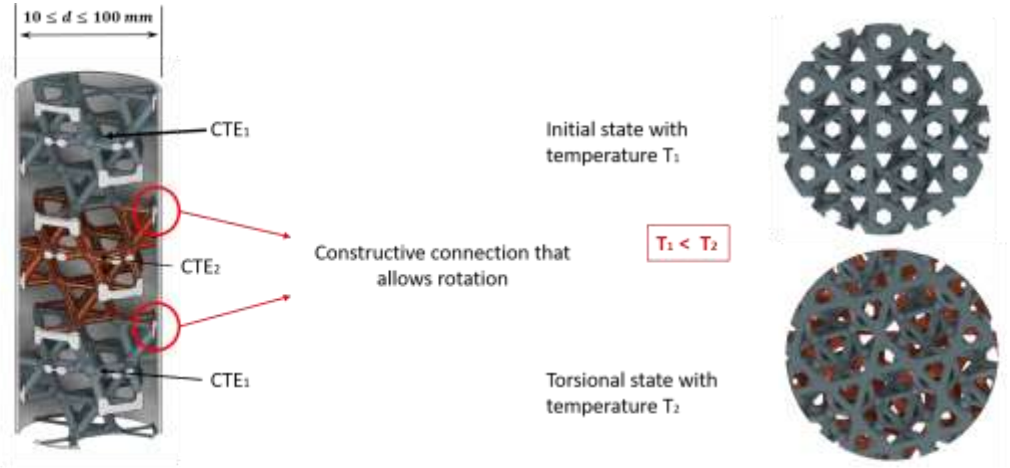
Personnel / Contacts

- Head of Institute:
  Prof. Ingomar Kelbassa
  ingomar.kelbassa@tuhh.de

- Senior Engineer:
  Dr.-Ing. Dirk Herzog (starting 01.11.2022)
  dirk.herzog@tuhh.de

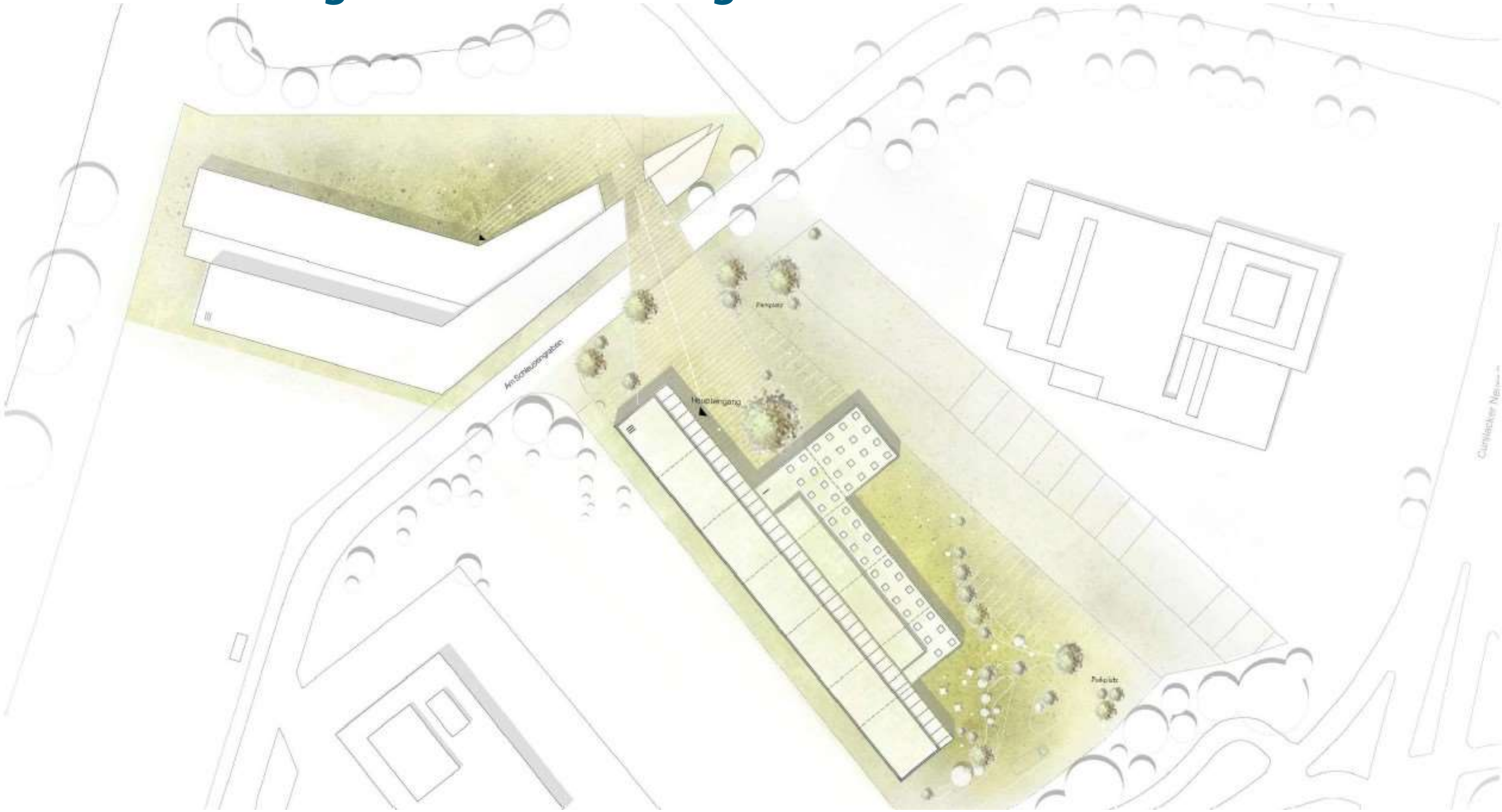
Current Topics

- 'Integration of components into adaptive geometries', (proposal in the frame of the DFG-CRC 'SmartReactors')
- 'Investigation of the influence of adaptive, additively manufactured burner structures on injection and mixing processes by combustion of single- and multi-phase H_2/NH_3 fuel mixtures' (proposal in DFG-SPP2419)
- 'Optimization and quality-assured production of hydrogen-carrying components for Emission-free flying' (proposal in LuFo)



TUHH Fraunhofer IAPT

Site plan of the existing and new building



intern

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East view

North view

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New Equipment

Carrier gas hot extraction

ELEMENTRAC ONH-p 2
(Eltra)

Climate chamber

Typ 3423/18
(Feutron)

KF Coulometer

KF Coulometer 899 +
Thermoprep 860
(Metrohm)

Universal testing machine

Zwick Z100
(Zwick Roell)

Sources: Eltra, Metrohm, Feutron, Zwick Roell

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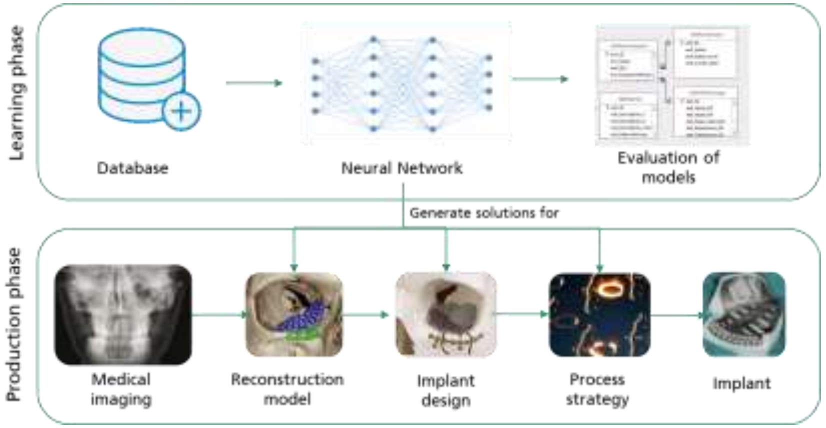
Recently startet projects

regional and global collaboration with experts

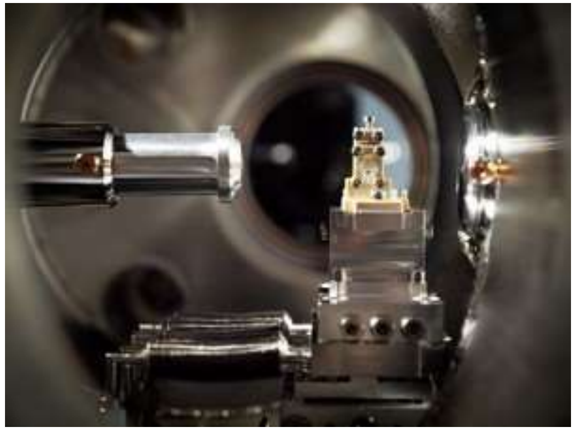
DIGIMED



- **End-to-end digital process workflow for medical implants**

UKE HAMBURG
HELMUT SCHMIDT UNIVERSITÄT

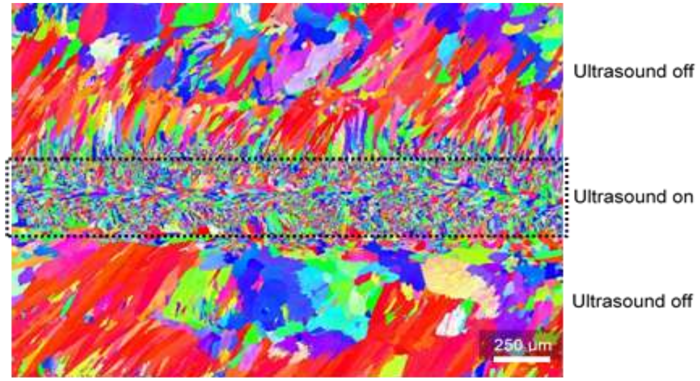
SPLASHH



- **Shaping Plasma Accelerators in Hanseatic City of Hamburg**
- **Powder bed based laser beam melting of copper**

DESY.
TUHH Technische Universität Hamburg

UltraGrain



- **Local grain fining in AM by ultrasound ➔ Tailored mechanical properties**
- **Development of multi-material topology optimization**

Fraunhofer IWS
RMIT UNIVERSITY

Meet uns @ Formnext

Booth E129 in Hall 12.0 (ground floor)

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Kontakt

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Fraunhofer IAPT

Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT

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Fraunhofer
IAPT

25.10.2022

Update to our initiave IAMHH®

Nora Jaeschke

What is IAMHH® again?

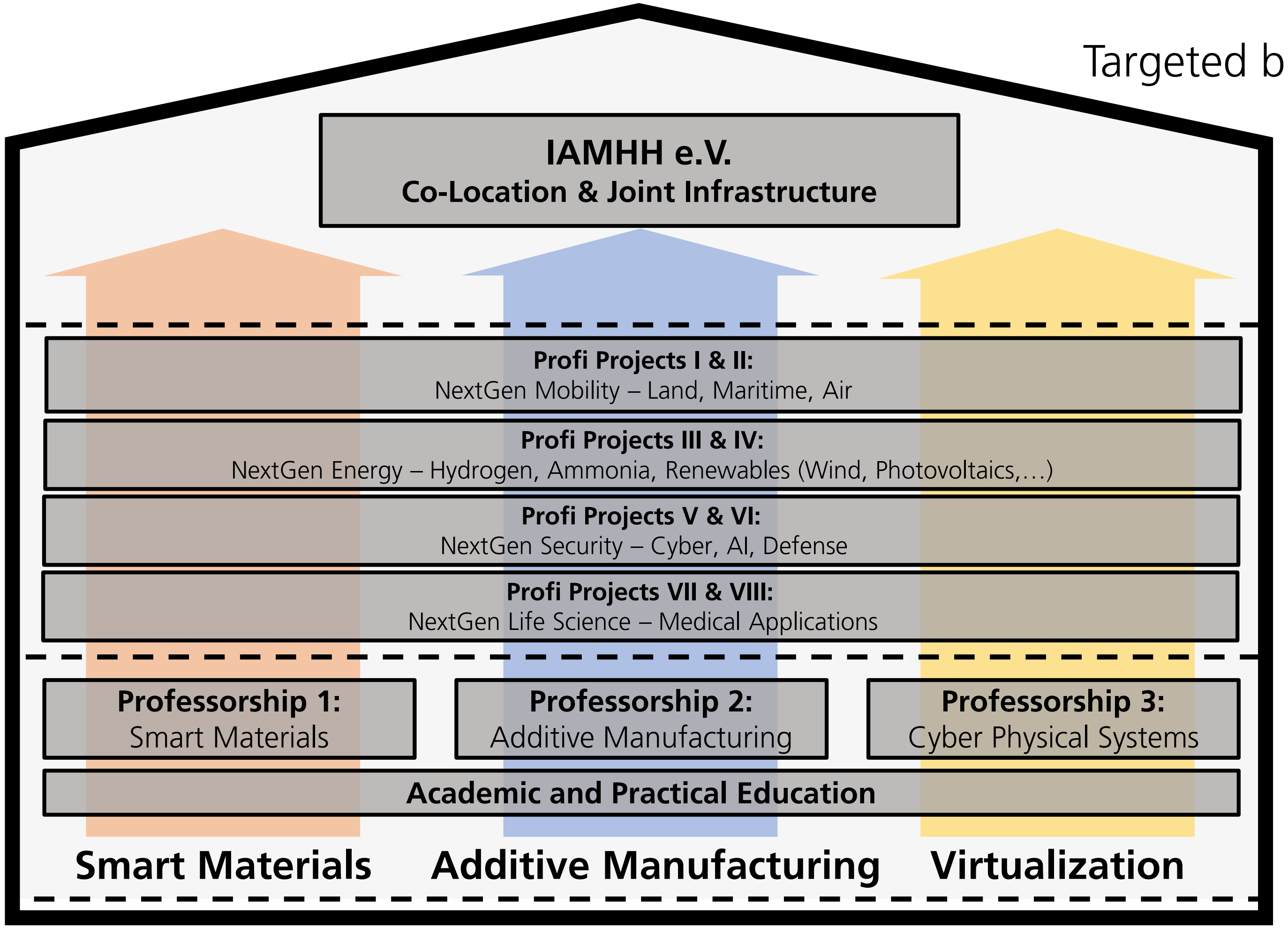
Short reminder

Industrialized Additive Manufacturing Hub Hamburg

- ✓ A large-scale, lighthouse project in the metropolitan region of Hamburg
- ✓ Creation and establishment of a product-driven and demand-oriented R&D ecosystem
- ✓ Focus on 3D-printing

Concept of IAMHH®

Industrialized Additive Manufacturing Hub Hamburg



Targeted budget for initial 5 years > 100 Mio. EUR

Cross-Cluster-Initiative:
shared infrastructure, system/plant technologies, location…

Collaborative projects

1. Funding initiative for Profi-Projects: „Innovation Focus 3D-Druck“
   → 3 Mio. EUR funding
2. More collaborative projects…

Science/Research in Hamburg

- Universitys
- Non-university R&D
- Technical colleges
- …

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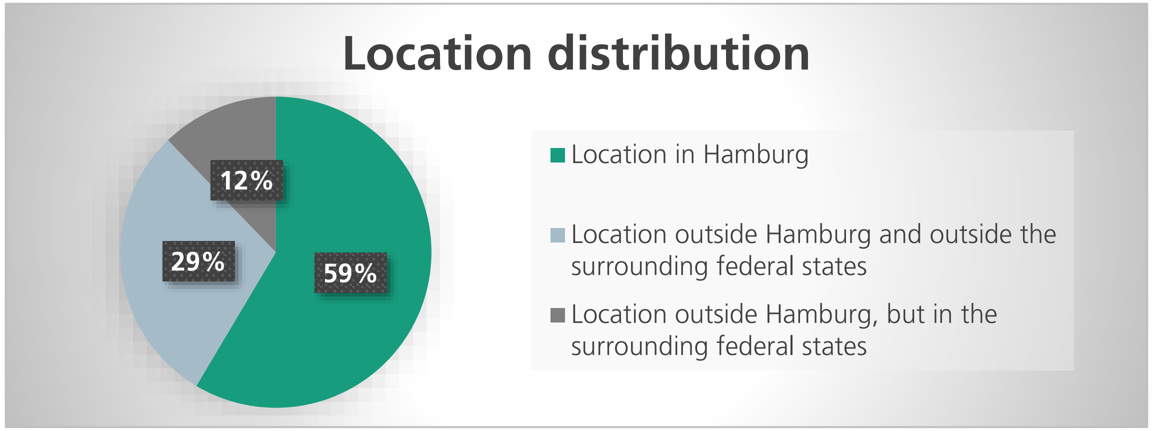
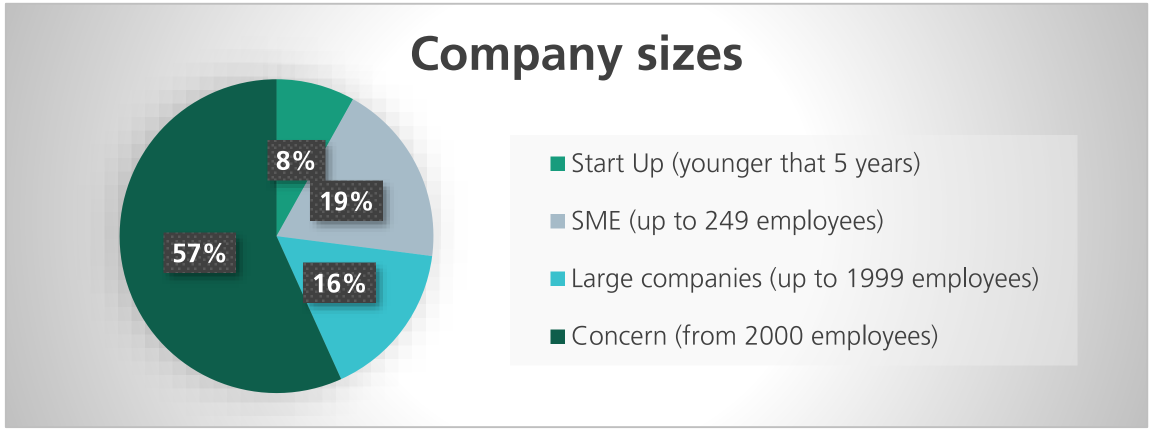
Current status of IAMHH®

What happened since April 2022?

- ✓ **First funding started already**
- ✓ **IAMHH® registered as a trademark**
- ✓ **More than 40 interested companies such as**
  - Airbus
  - Siemens
  - TKMS
  - Autoflug
  - SLM Solutions
  - ZF
  - Zellerfeld
  - UKE

  and many more





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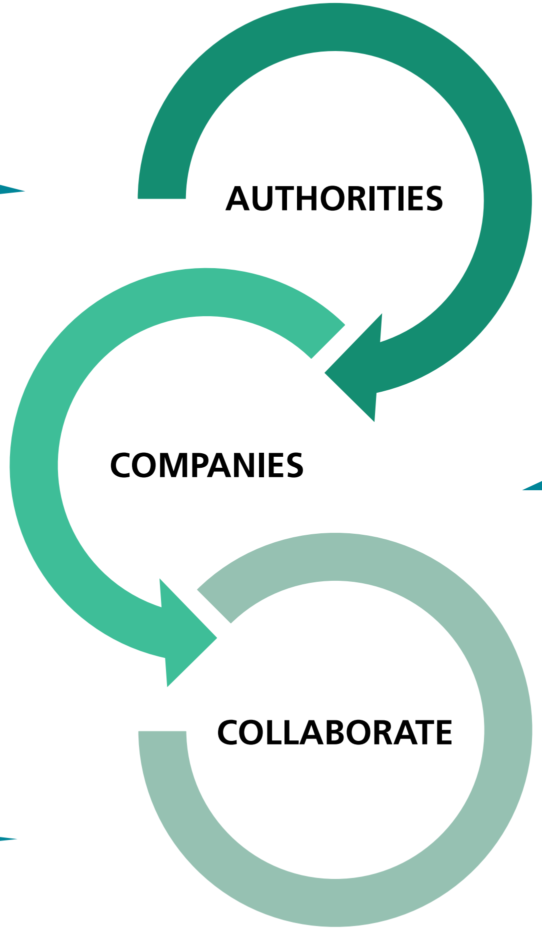
Next steps for our initiative IAMHH®

Negotiations with the **authorities** in terms of funding conditions



Conducting further **topical deep dives** and clustering first **key topics**

Connecting companies and initiating first **project ideas**

Thank you very much for your attention!

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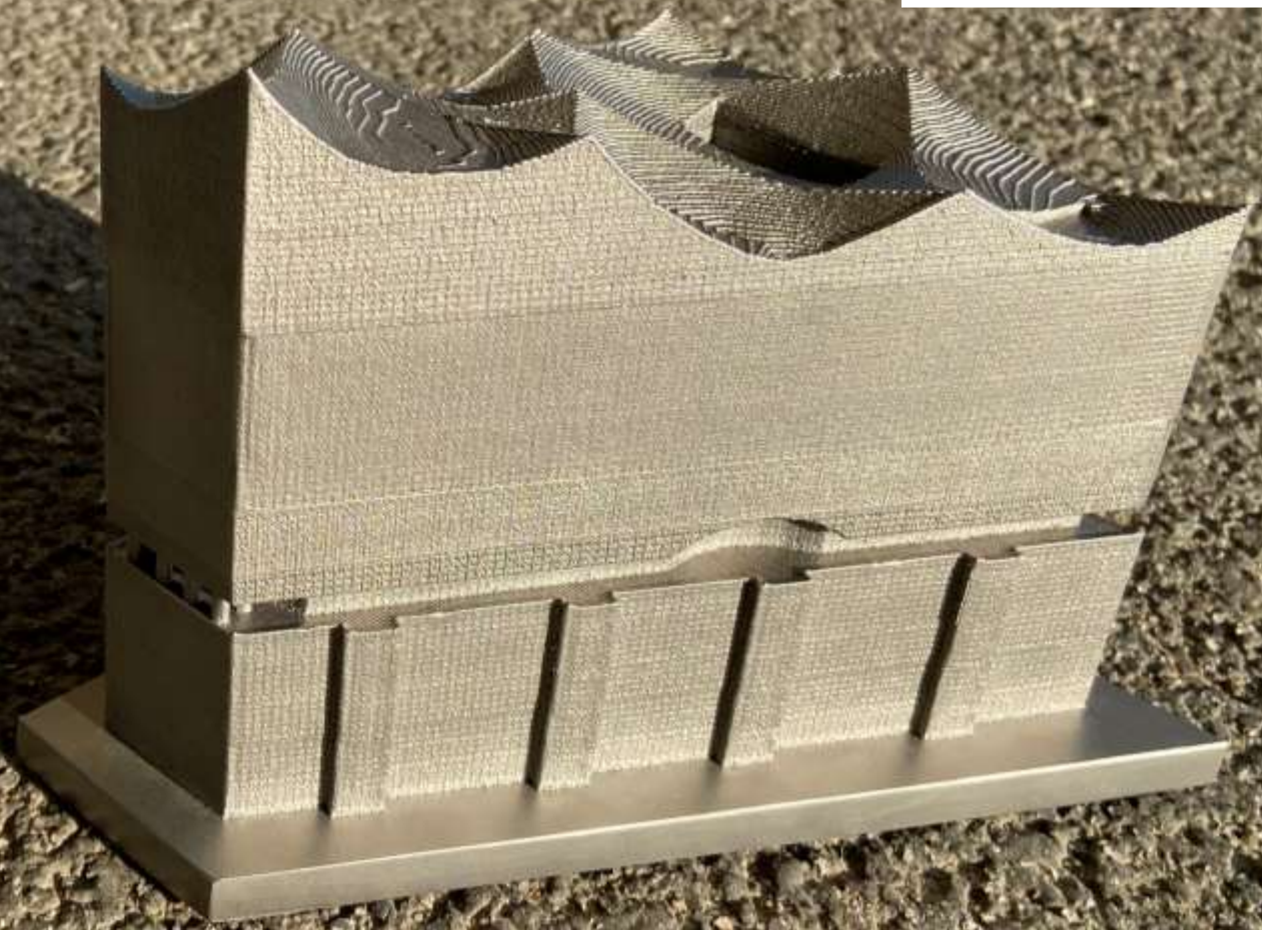


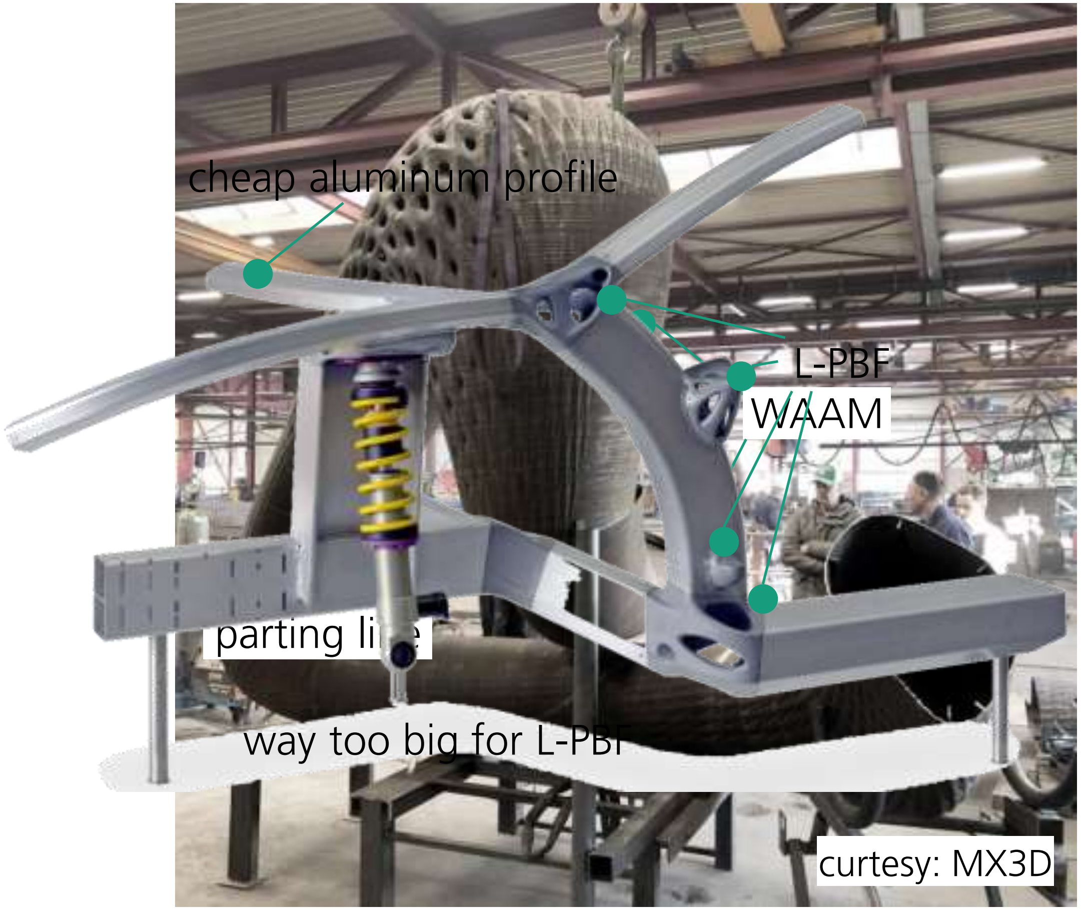
Markus Heilemann, M. Sc.
DED Systems

Hybrid Additive Manufacturing

Why and when should you consider hybrid AM?

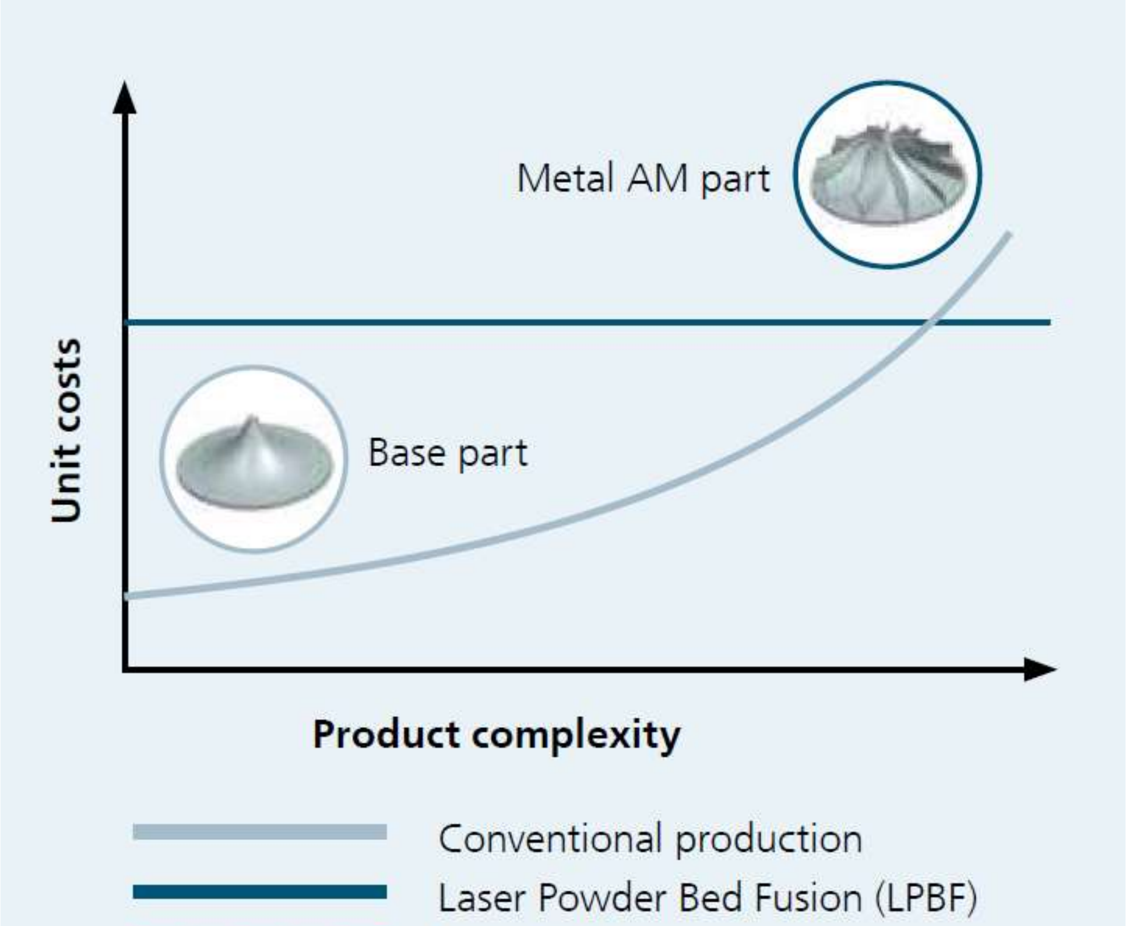
Limiting factors in 3D-Printing

- Cost aspects
- Size (e.g. build volume)
- Complexity (e.g. overhangs)
- Accessibility (e.g. collision of the print head)



Why and when should you consider hybrid AM?

Looking closer into the costs

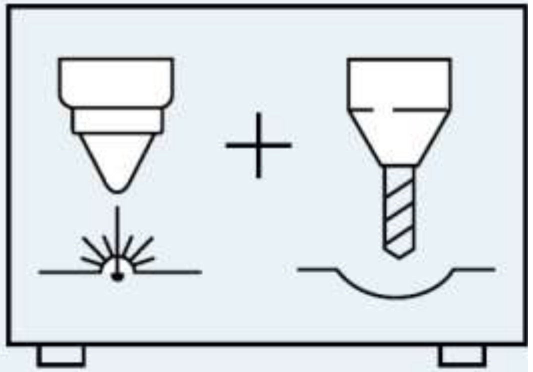


Definition of Hybrid AM

What is the focus of the deep dive?

Definition 1:

Combination of different production technologies in one machine



ᶜ this deep dive

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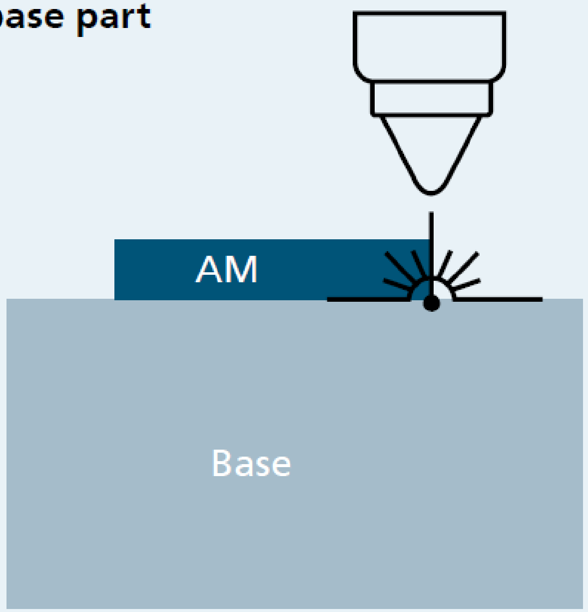
How to combine different parts?

Option 1:

Printing directly on base part



Option 1: Printing directly on a part/substrate

ADDITIVE ALLIANCE

Main advantages

- Cost savings in the conventional volume
- No additional joining process necessary
- "full-faced" weld seam

Main challenges

- Limited AM processes (binder jetting not possible)
- Parting plane for powder bed processes only horizontal
- Excessive clamping, positioning and measuring

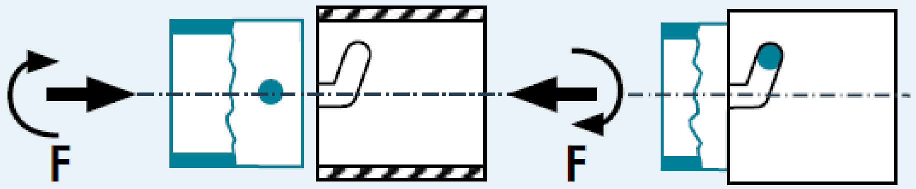
Option 2: Joining of a conventional part with an AM part

<u>Main advantages</u>
- Cost savings in the conventional volume
- Very large parts possible also with powder bed processes
- Suitable for all AM technologies

<u>Main challenges</u>
- Additional manufacturing step → costs!
- Distortion may occur → fixture + heat treatment
- Material pairing / weld seam characteristics may differ

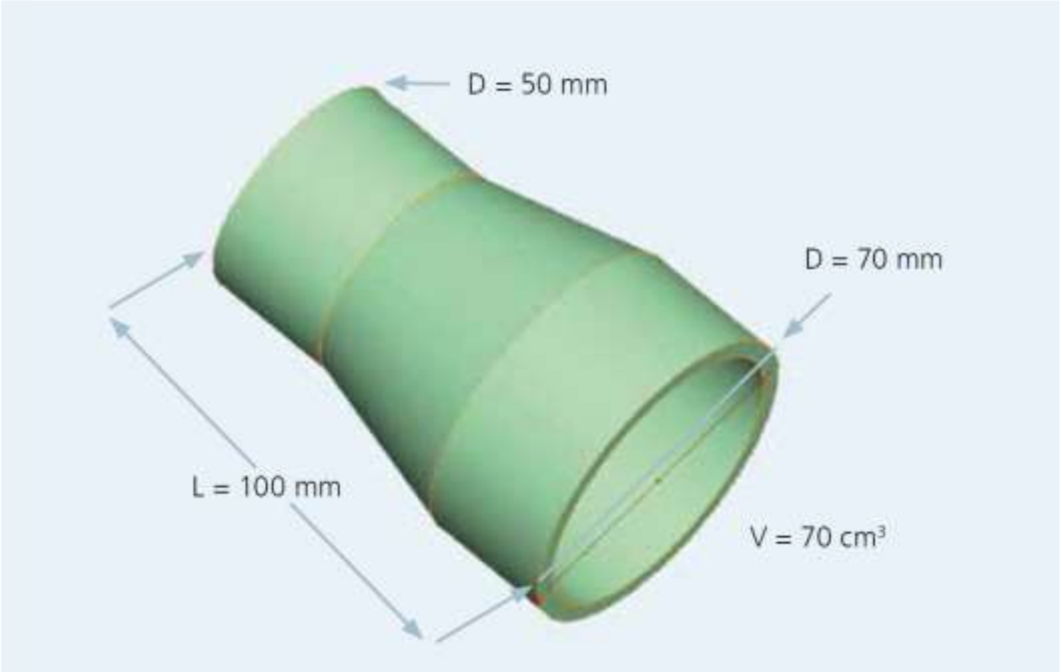
Option 2: Joining of a conventional part with an AM part

Table of different joining zones designs

Joining zone design	Principle design	Advantages	Disadvantages
Butt joint with integrated V-groove		■ Positioning aid integrated in the joining zone	■ Accurate mechanical preparation of the conventional joining partner necessary
Bayonet		■ Function integration: positioning and clamping ■ Defined rotational orientation of the parts to each other	■ Complex mechanical preparation of the conventional joining parts ■ Higher effort for automated pre-weld part assembly

Identification of cost-saving potentials

What are the €/cm³ of printing costs that you can save?



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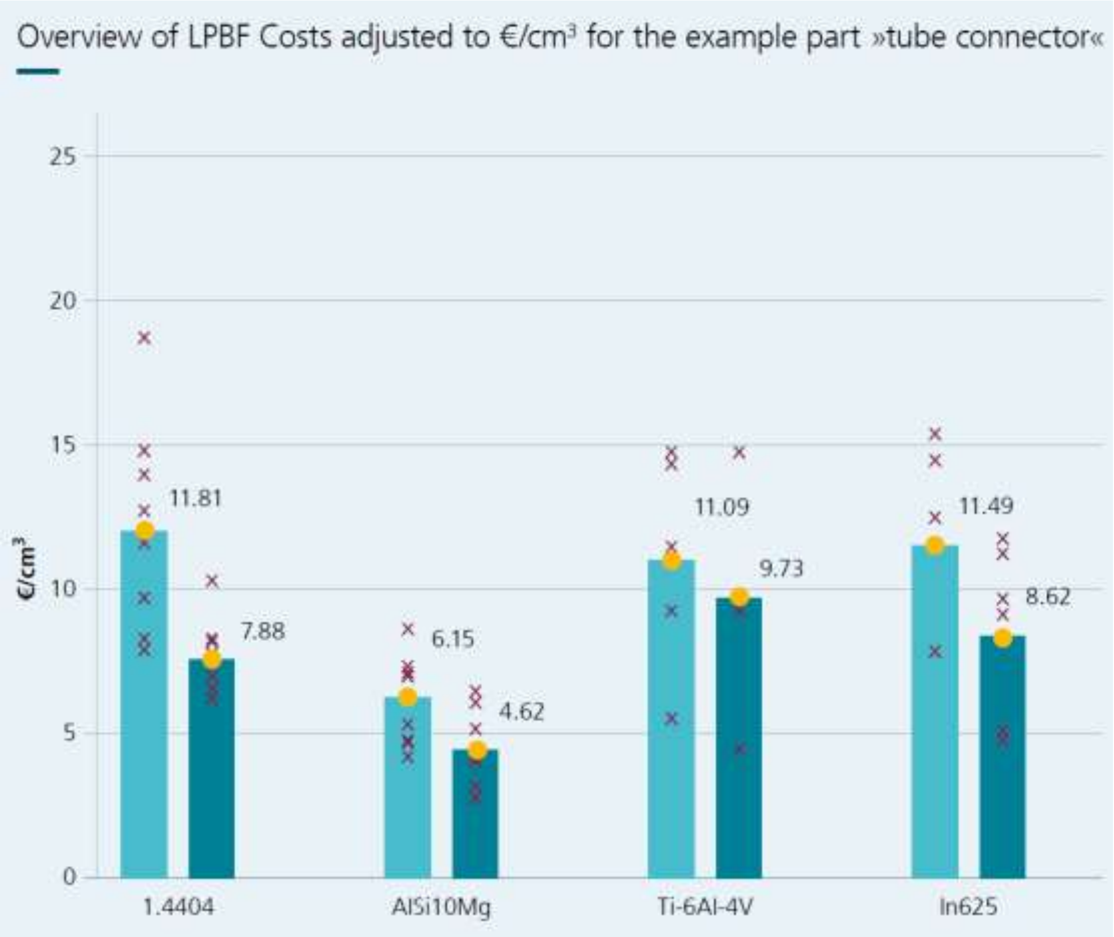
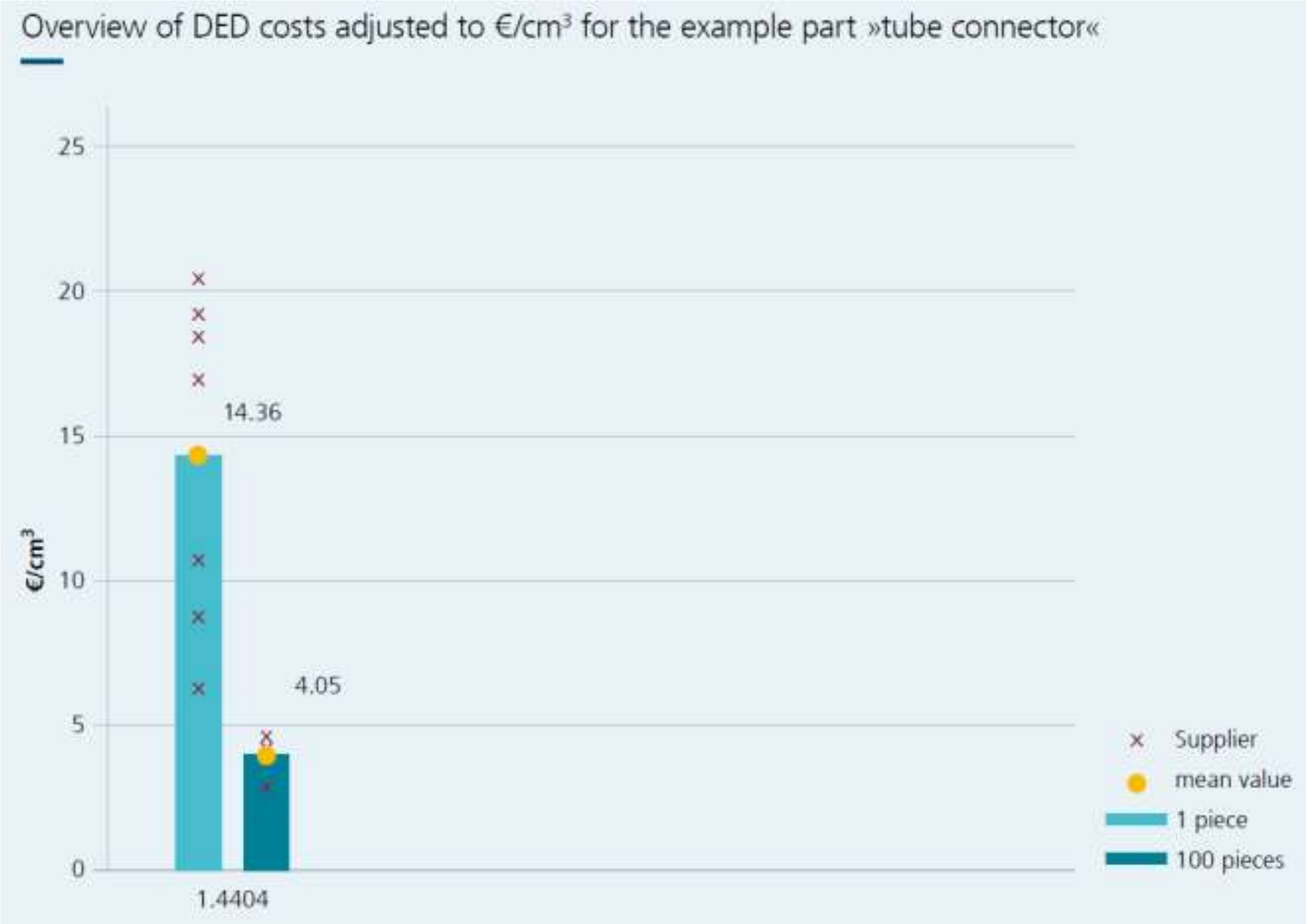
Identification of cost-saving potentials

What are the €/cm³ of printing costs that you can save?





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Summary

Evaluation matrix for assessing part suitability

Suitable for	Joining of AM and conven-tional parts	Printing on conventional part (LPBF)	Printing on conventional part (DED)	LPBF only	DED only	Conventional
Large dimensions	●	●	●	○	●	●
Bulky volume	◐	○	●	○	◐	●
High part complexity	●	◐	◐	●	○	○
High surface quality of the printed surface	◐	◐	○	◐	○	●
Light-weight design	●	●	◐	●	○	◐
High number of part variants or customisable features	●	●	◐	●	◐	○

● good ◐ neutral ○ poor

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Markus Heilemann, M. Sc.
DED Systems

Hybrid Additive Manufacturing

Design criteria for selected welding processes

	Laser beam	Electric arc	Electron beam
Low investment costs	◔	●	◔
Filigree weld seams possible	●	◑	●
Low thermal distortion	●	◔	●
High welding depth/penetration	●	◔	●
High gap bridging	◔	●	◔
High welding velocities	●	◔	●
Low welding environment requirements	◔	●	◔
Low safety requirements	◔	●	◔
Low welding preparation requirements	◔	●	◔

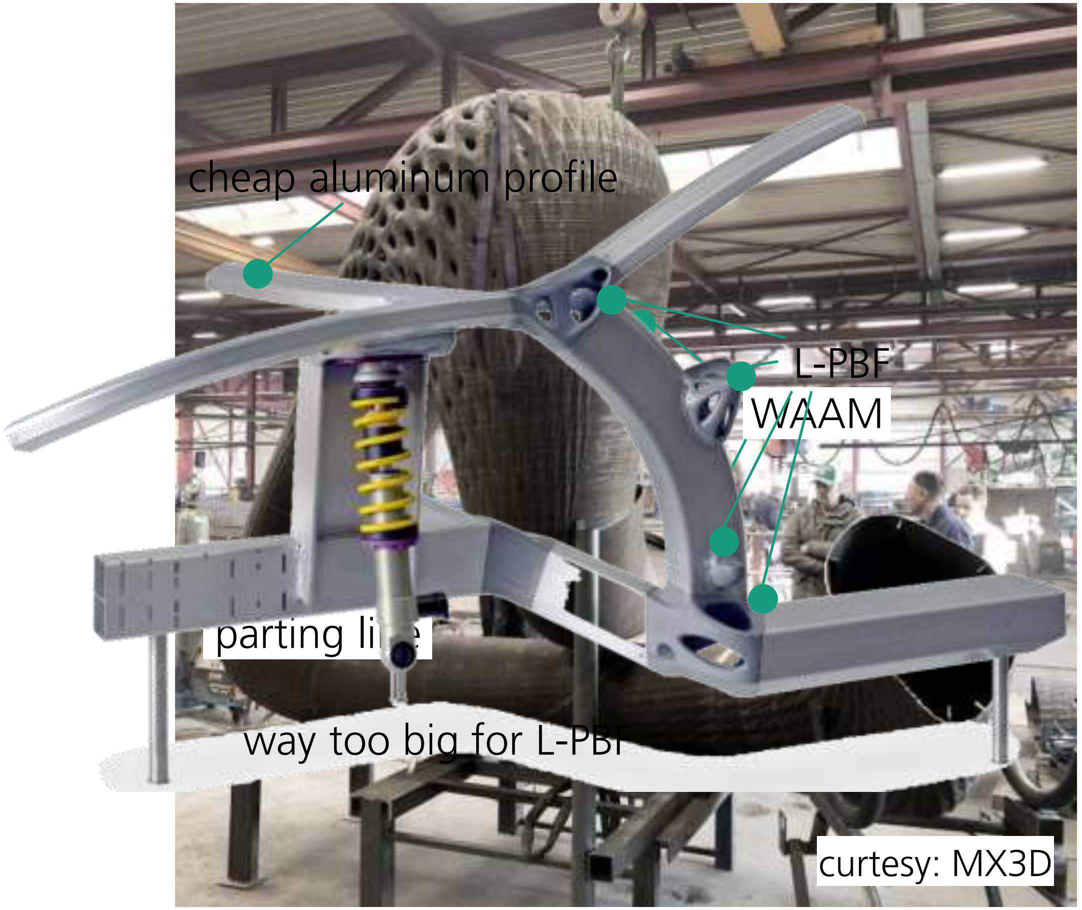
● good
◑ neutral
◔ poor

Why?

What is the problem? Why is this issue important?

Printing parts is in some cases limited due

- Cost aspects
- Size (e.g. build volume)
- Complexity (e.g. overhangs)
- Accessibility (e.g. collision of the print head)



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What?

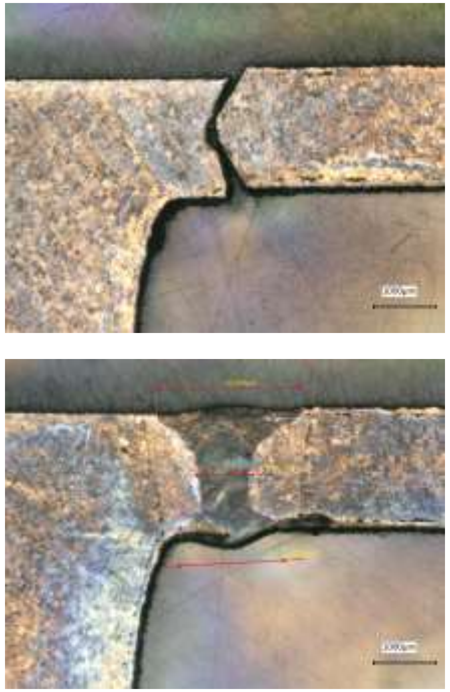
What will be investigated? What contents are planned?

- Overview of joining processes & hybrid AM parts
- Closer look at how to design the joining zone for welding processes
- Characterization of the welded joint for laser beam welded automotive steel and aerospace titanium
- Evaluation of the economical and ecological aspects of an Hybrid AM process chain

How?

How are the results developed? What is the experimental method?

- Literature research for the current state of the art of Hybrid AM
- Experimental investigation of different joining zone designs
- Micrographs and hardness tests of the welded joint for two materials




curtesy: MX3D

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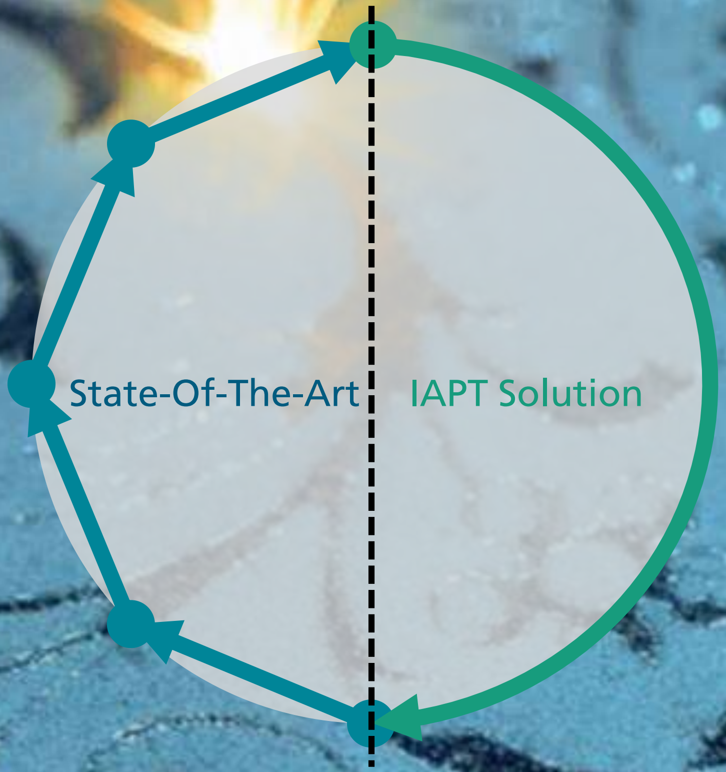
Fraunhofer IAPT

Philipp Kohlwes
Head of L-PBF Team

"Why curves are better for curved contours than straight lines"



Person A
Draw a circle!

No Problem!

LPBF-Machine
Hold my beer!

The Authors




Jan Johannsen, M.Sc.
Research Associate L-PBF

Philipp Kohlwes, Dipl.-Ing.
Head of L-PBF Team

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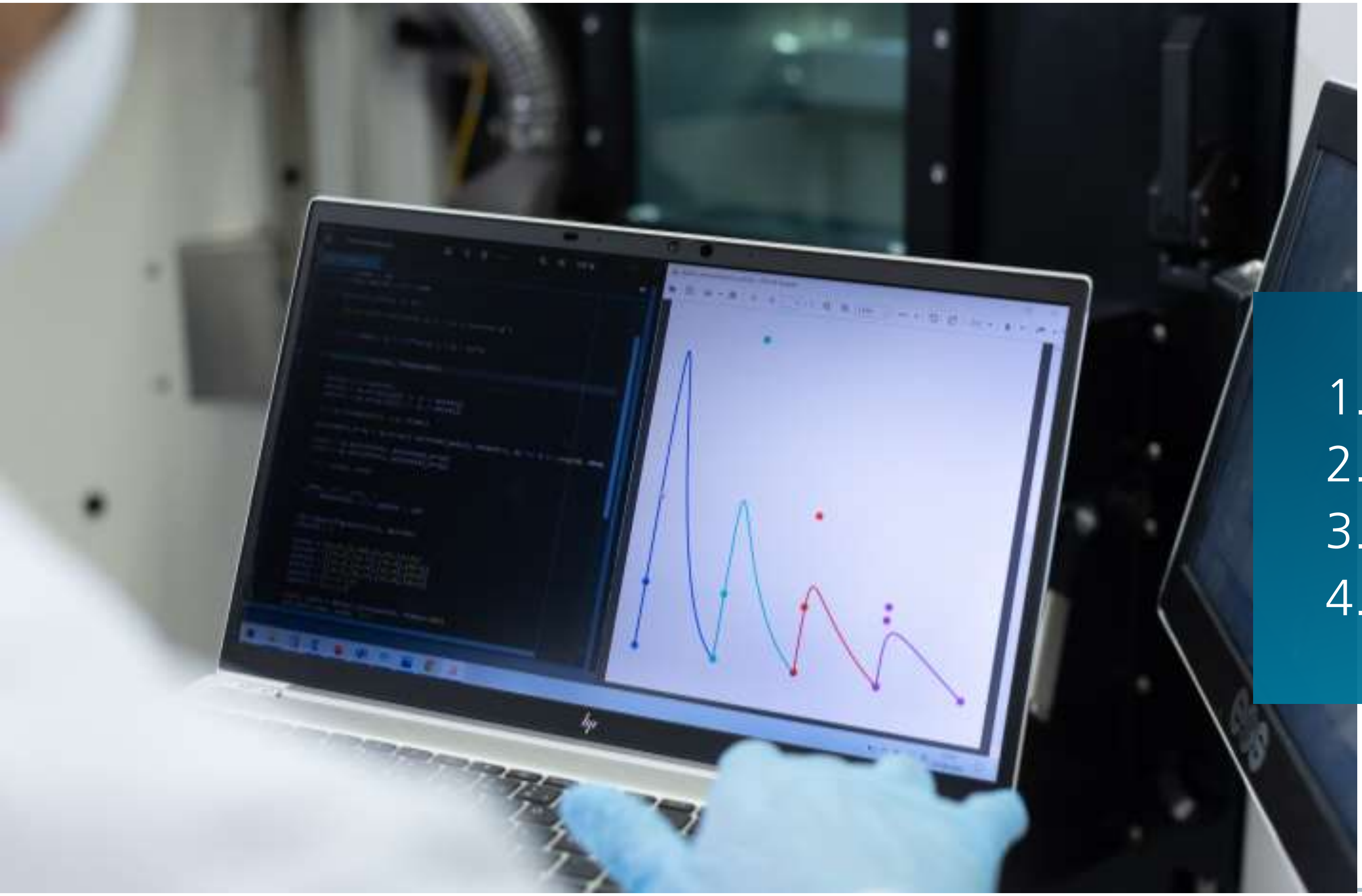
Agenda



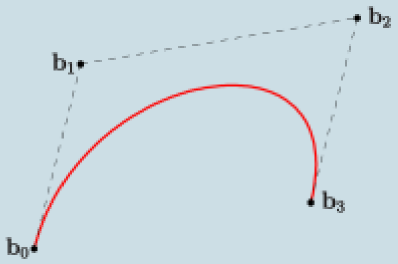
1. Motivation
2. Approach
3. Results
4. Conclusion

Motivation

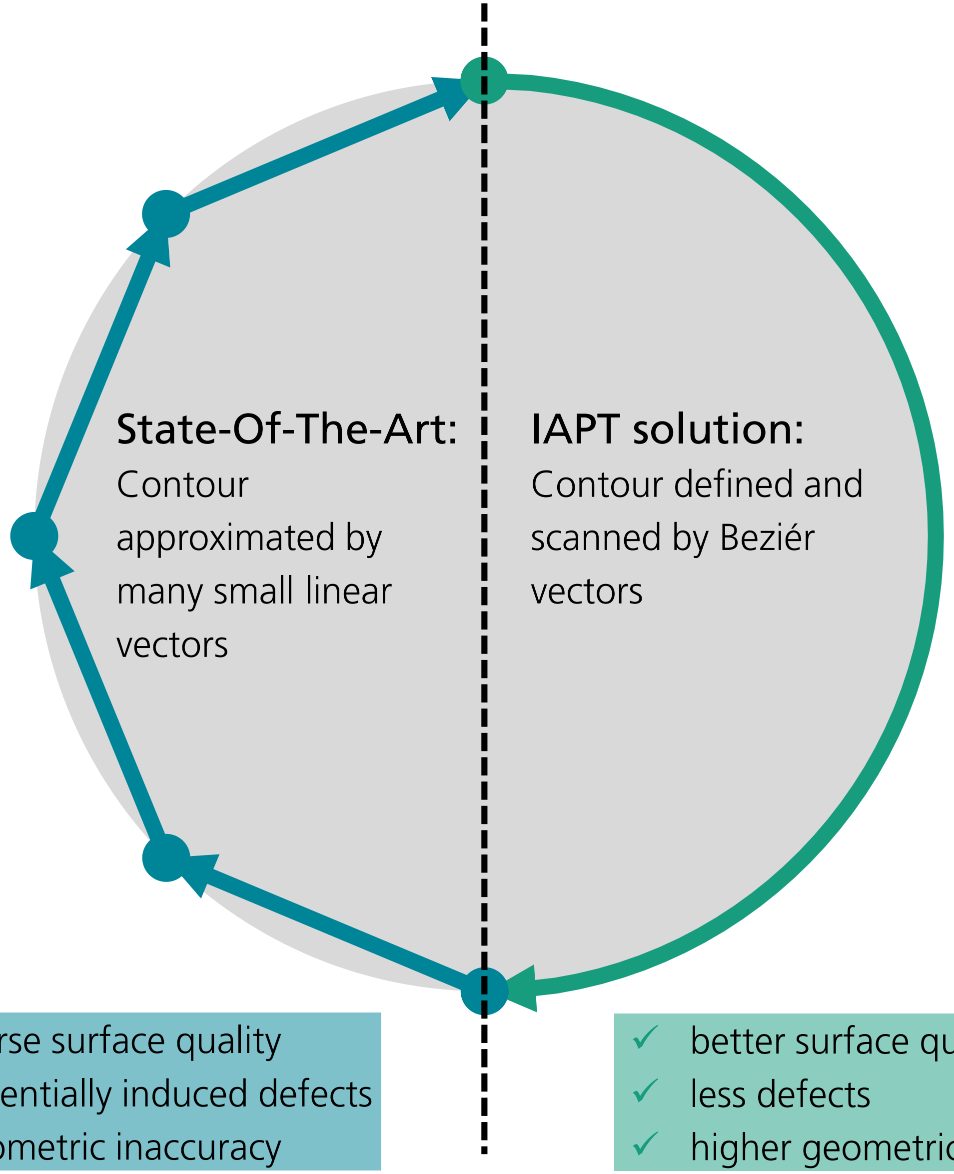
Utilizing Beziér vectors for contour scan

Beziér vector:

A set of discrete "control points" defines a smooth, continuous curve by means of a formula



- ✓ Beziér vectors are ready to use with common scanner systems of L-PBF machines
- × …but are not utilized, yet



- × worse surface quality
- × potentially induced defects
- × geometric inaccuracy

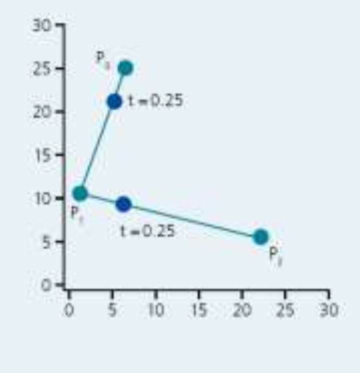
- ✓ better surface quality
- ✓ less defects
- ✓ higher geometric accuracy

Motivation

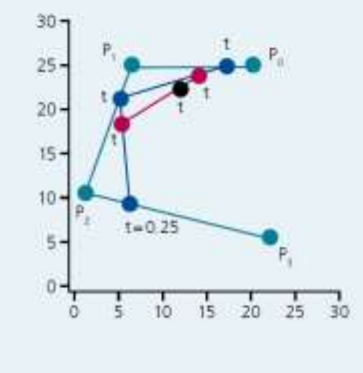
Background Information about Bézier Curves

A Bézier curve is a parametric curve defined by a set of points (P0, …, Pn), a starting point, an end point, and usually further control points. The number of points, i.e. the value of n, defines the order of a Bézier curve.

2nd Order



3rd Order



Motivation

Potentials of Bézier Curves for L-PBF

	CAD Compatibility	Dimensional Accuracy	Surface Roughness	Data Handling	Productivity
Current Solution	◑	◕	◕	◔	◑
Freeform Curves	?	?	?	?	?

● *good/high* → ◔ *limited/low*

Approach

Approach

Overview

Design

Design of Demonstrator

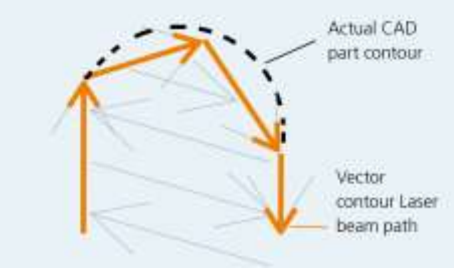
Control

Integration of external control unit

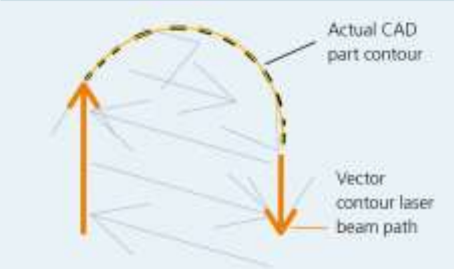
Program of Bézier curves and laser paths

Print

Printing the Demonstrator with state-of-the-art process

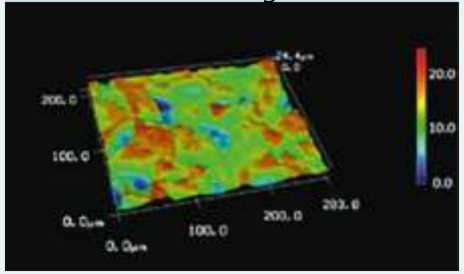


Printing the Demonstrator with Bézier curves



Measure

Measuring the surface roughness



Measuring the geometrical accuracy

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Approach
Overview

Design

Design of Demonstrator

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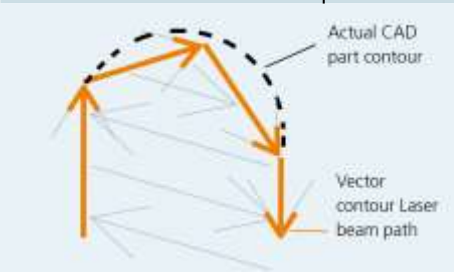
Integration of
external control unit

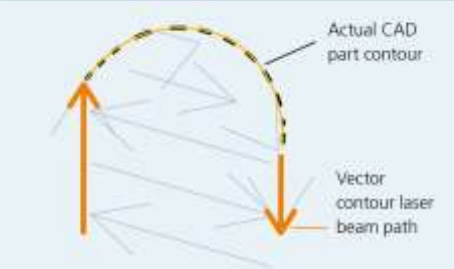
Program of Bézier curves
and laser paths

Print

Printing the Demonstrator
with state-of-the-art process

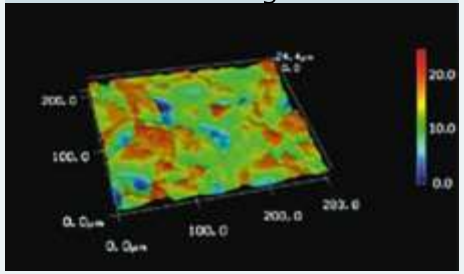


Printing the Demonstrator
with Bézier curves



Measure

Measuring the
surface roughness



Measuring the
geometrical accuracy

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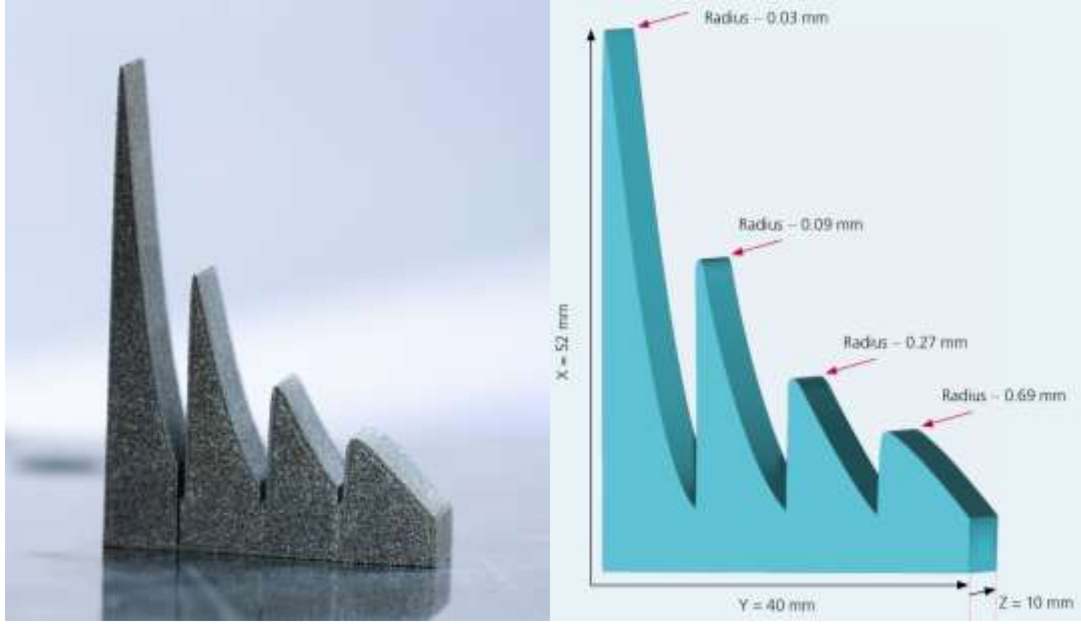
Approach
Design of Demonstrator



Demonstrator features to be considered

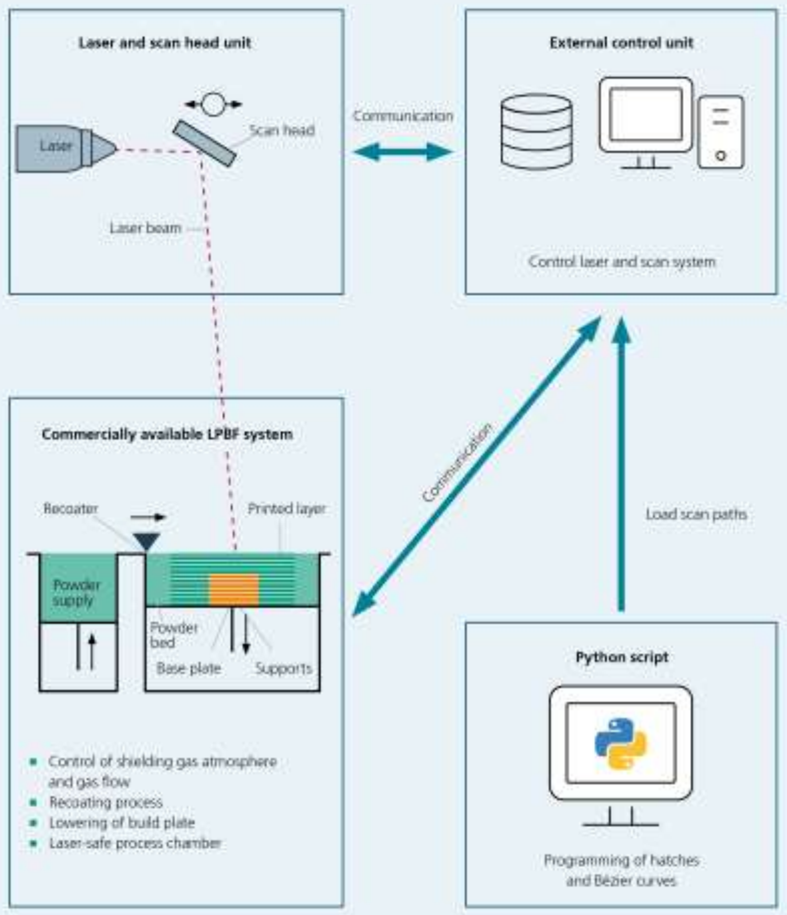
- freeform surfaces with various curvatures
- manually programmable Bézier curves
- repeating 2D geometry for manufacturing in a lab envioriement

Approach

Integration of external control unit

Machine Set-up

- industry-standard L-PBF body
- industry-standard laser and scan head units
- external control unit to synchronize L-PBF machine body with laser and scan head unit
- programming of hatches and Bézier curves via python script



Approach

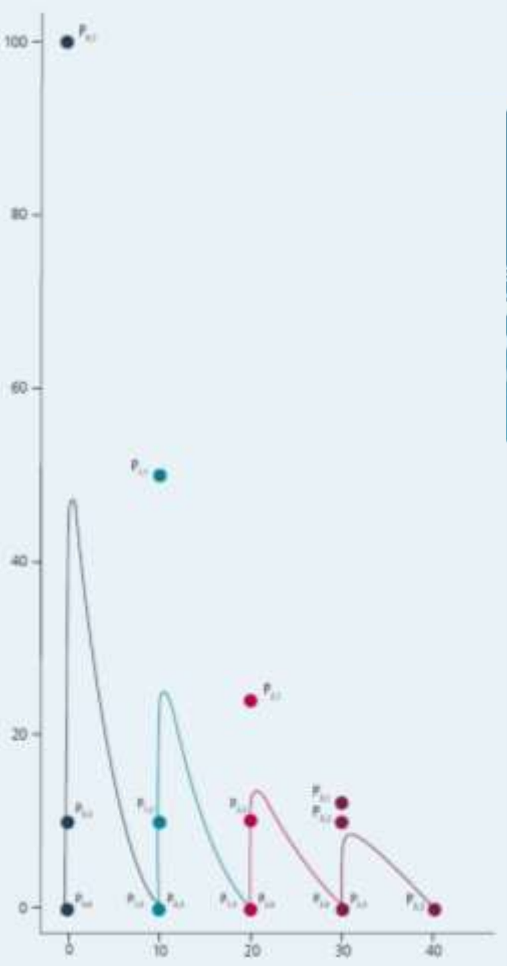
Program of Bézier curves and laser paths

An arbitrary starting point S = (x, y) results in the following Bézier curve control points:

For B_0	For B_1	For B_2	For B_3
$P_{0,0}$ = (x, y)	$P_{1,0}$ = (x + 10, y) = $P_{0,3}$	$P_{2,0}$ = (x + 20, y) = $P_{1,3}$	$P_{3,0}$ = (x + 30, y) = $P_{2,3}$
$P_{0,1}$ = (x, y + 100)	$P_{1,1}$ = (x + 10, y + 50)	$P_{2,1}$ = (x + 20, y + 24)	$P_{3,1}$ = (x + 30, y + 12)
$P_{0,2}$ = (x, y + 10)	$P_{1,2}$ = (x + 10, y + 10)	$P_{2,2}$ = (x + 20, y + 10)	$P_{3,2}$ = (x + 30, y + 10)
$P_{0,3}$ = (x + 10, y)	$P_{1,3}$ = (x + 20, y)	$P_{2,3}$ = (x + 30, y)	$P_{3,3}$ =(x + 40, y)

Starting point S = (0,0) results in the following Bézier curve control points.
The resulting Bézier curves are shown in Figure 13.

For B_0	For B_1	For B_2	For B_3
$P_{0,0}$ = (0,0)	$P_{1,0}$ = (10,0)	$P_{2,0}$ = (20,0)	$P_{3,0}$ = (30,0)
$P_{0,1}$ = (0,100)	$P_{1,1}$ = (10,50)	$P_{2,1}$ = (20,24)	$P_{3,1}$ = (30,12)
$P_{0,2}$ = (0,10)	$P_{1,2}$ = (10,10)	$P_{2,2}$ = (20,10)	$P_{3,2}$ = (30,10)
$P_{0,3}$ = (10,0)	$P_{1,3}$ = (20,0)	$P_{2,3}$ = (30,0)	$P_{3,3}$ = (40,0)



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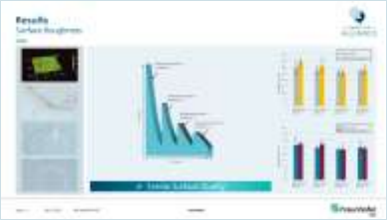
Results

Results

Overview

1 Surface Roughness

✓ S_a measured with laser scanning confocal microscope

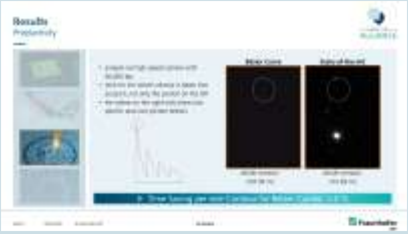


2 Geometric Accuracy

✓ Accuracy measured using optical microscope at 200x magnification

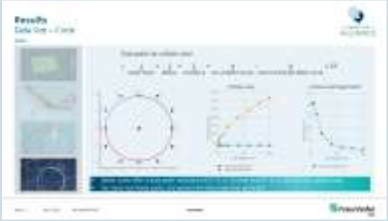
3 Productivity

✓ Exposure time measured using video capturing with a high-speed camera



4 Data Size

✓ Amount of data points for contour calculated



Results

Overview

1 Surface Roughness

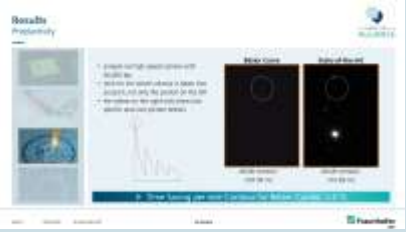
- ✓ S_a measured with laser scanning confocal microscope

2 Geometric Accuracy

- ✓ Accuracy measured using optical microscope at 200x magnification

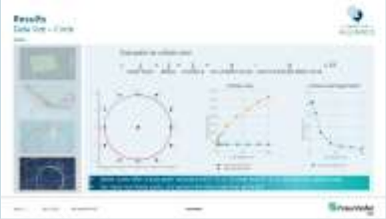
3 Productivity

- ✓ Exposure time measured using video capturing with a high-speed camera

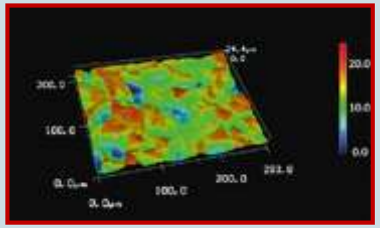


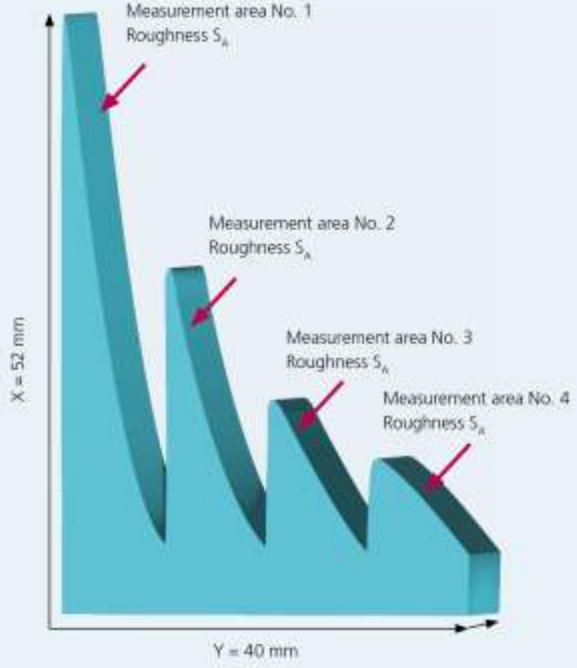
4 Data Size

- ✓ Amount of data points for contour calculated

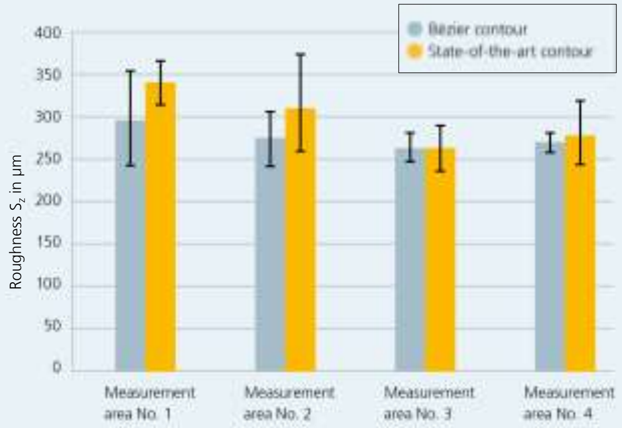


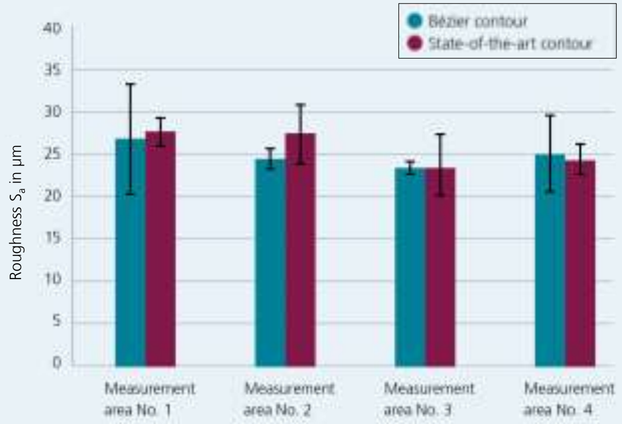
Results
Surface Roughness



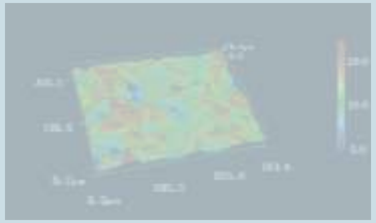


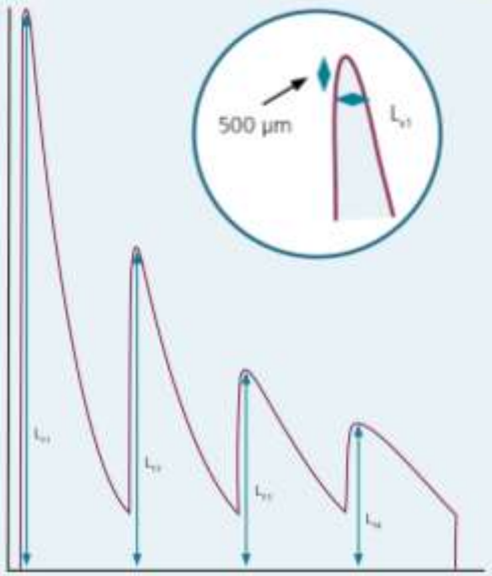
➢ Similar Surface Quality





Results
Geometric Accuracy (1/2)

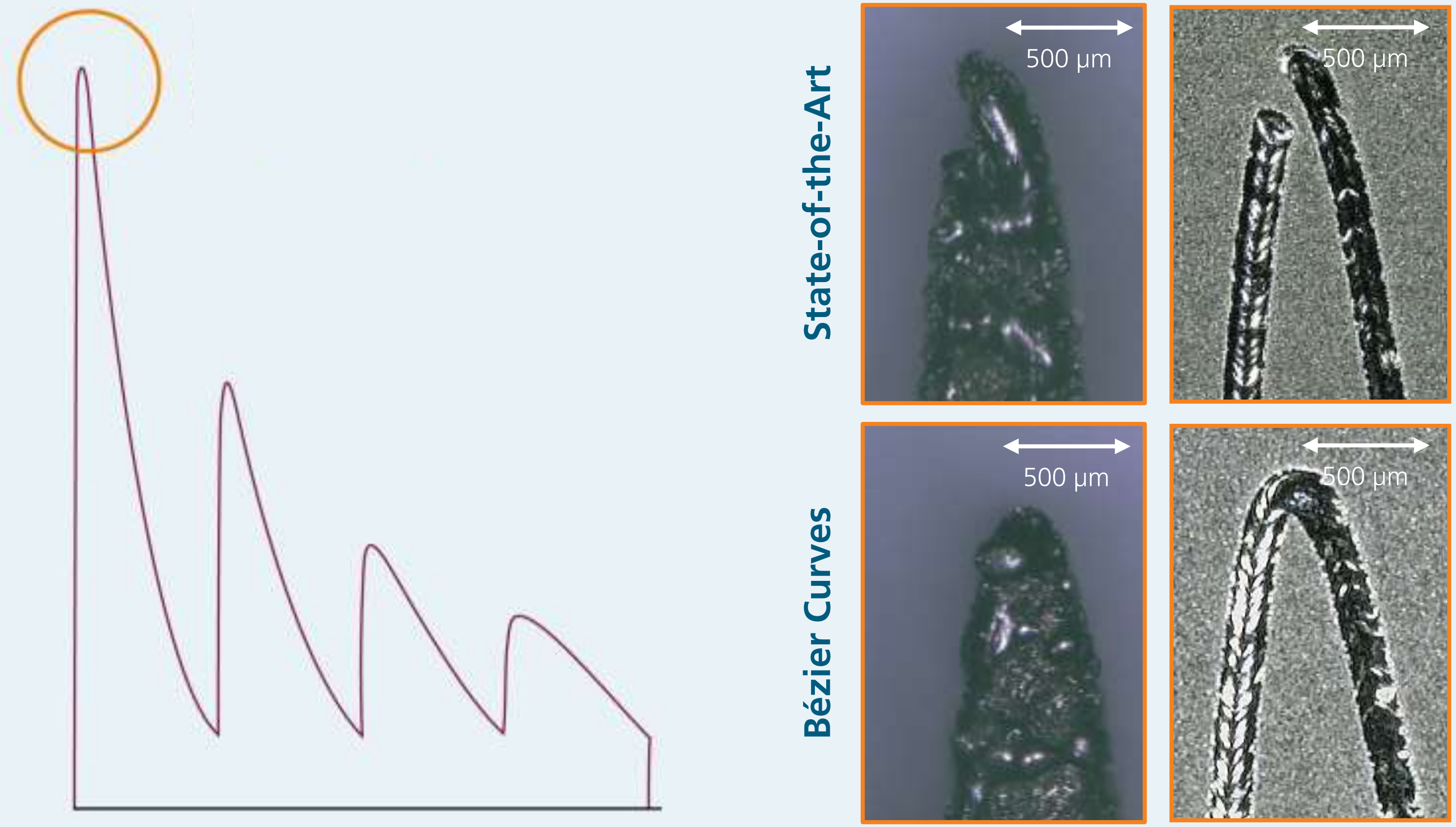




Measure-ment	CAD	Bézier Contour		State-of-the-Art Contour	
	Length in µm	Measured Length in µm	Deviation from CAD in µm	Measured Length in µm	Deviation from CAD in µm
L_{Y1}	51,903	52,322	419	52,401	498
L_{Y2}	29,767	29,981	214	30,043	276
L_{Y3}	18,402	18,524	122	18,539	137
L_{Y4}	13,374	13,493	119	13,498	124
L_{X1}	310	508	198	498	188

➢ Similar Geometric Accuracy

Results
Geometric Accuracy (2/2)

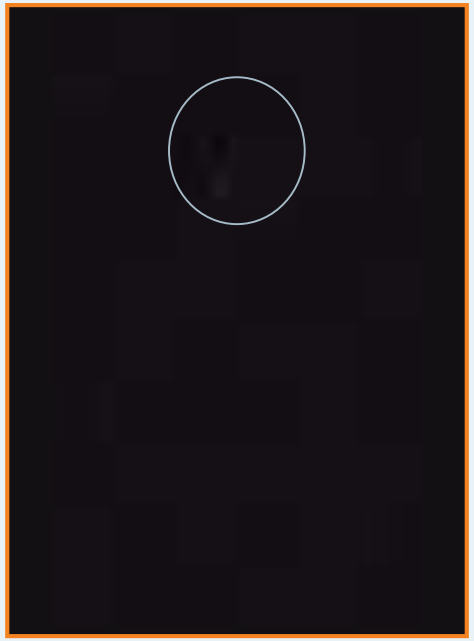


➢ No Contour Defect for Bézier Approach

Results
Productivity

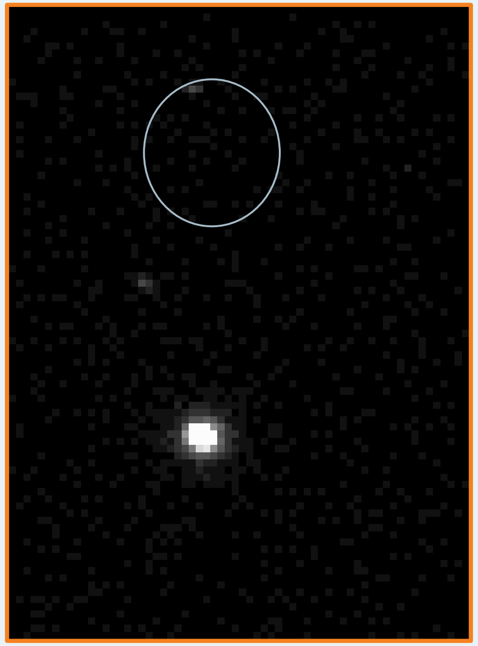
- analysis via high speed camera with 66,000 fps
- time for the whole contour is taken into account, not only the section on the left
- the videos on the right only show one specific area (see picture below)

Bézier Curve



whole contour:
207.99 ms

State-of-the-Art

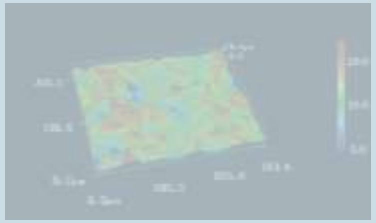


whole contour:
210.89 ms

➢ Time Saving per one Contour for Bézier Curves: 1.4 %

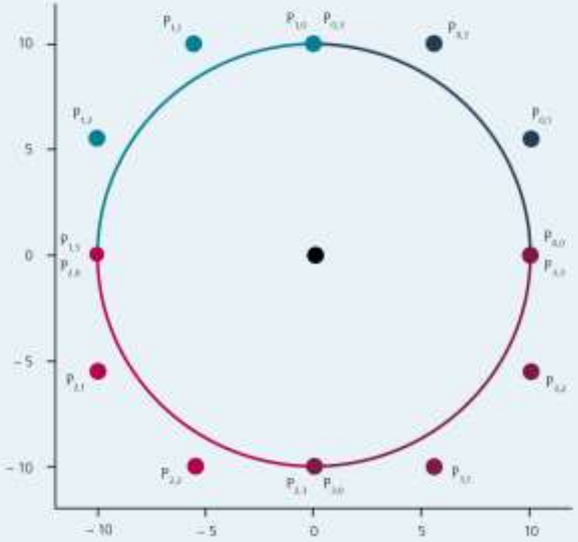
Results

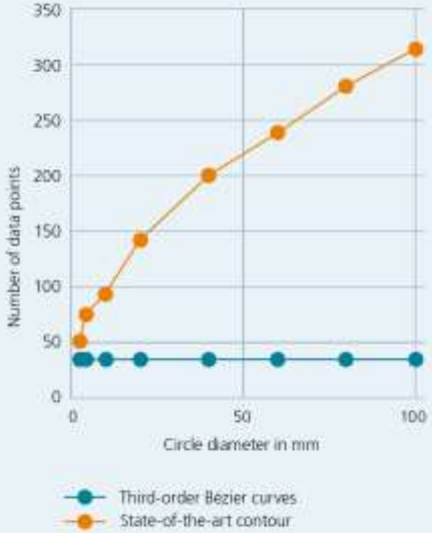
Data Size – Circle

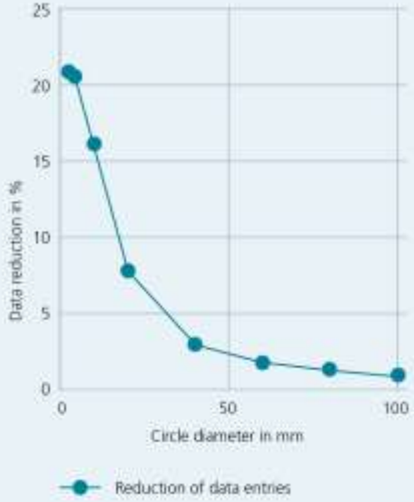


Data points for a Bézier circle

$$= \underbrace{1}_{Center\ Point} + \underbrace{1}_{Radius} + \underbrace{1}_{constant\ k} + \underbrace{4}_{No.\ of\ Bézier\ Curves} \cdot \underbrace{4}_{Control\ Points\ per\ Bézier\ Curve} = 19$$



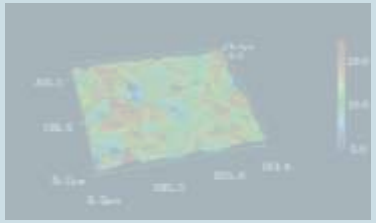




- ➢ Bézier cuves offer a data point reduction of 87 % (r=10 mm) and 91 % (r=20 mm) for contour only
- ➢ the more non-linear paths, the greater the data reduction potential

Results

Data Size – Demonstrator




	State-of-the-Art	Bézier Curves	Benefits of Bézier Curves
Data points of contour	398	24	94 %
Data points of contour and linear hatches	4,128	3,754	9 %

- ➢ Bézier cuves offer a data point reduction of 94 % (contour only) and 9 % (contour and linear hatch)
- ➢ Bézier curves could also be used for hatches in the future, thus decreasing the volume of data even more

Conclusion

● *good/high* → ◔ *limited/low*	CAD Compatibility	Dimensional Accuracy	Surface Roughness	Data Handling	Productivity
Current Solution	◐	◕	◕	◔	◐
Freeform Curves	●	◕	◕	●	◕

CAD Compatibility: Using freeform curves, the scan vectors are created directly from the CAD data. This leads to a reduced degradation of data quality as well as to fewer steps in the digital process chain.

Dimensional Accuracy: The state-of-the-art contour and the Bézier contour show similar results. The state-of-the-art contour showed one discontinuity resulting from an end/start point of two vectors. With the Bézier method, on the other hand, this defect was not visible.

Surface Roughness: Bézier curves for the contour does not provide a significant advantage over today's technology with respect to the surface quality of the demonstrator part investigated here. At the same time, it presents no disadvantage either.

Data Handling: A significant reduction in the required amount of data is possible using freeform curves.

Productivity: The productivity can be potentially increased using Bézier curves. However, a deeper understanding is necessary to establish for which geometric features Bézier curves present a time-saving method.

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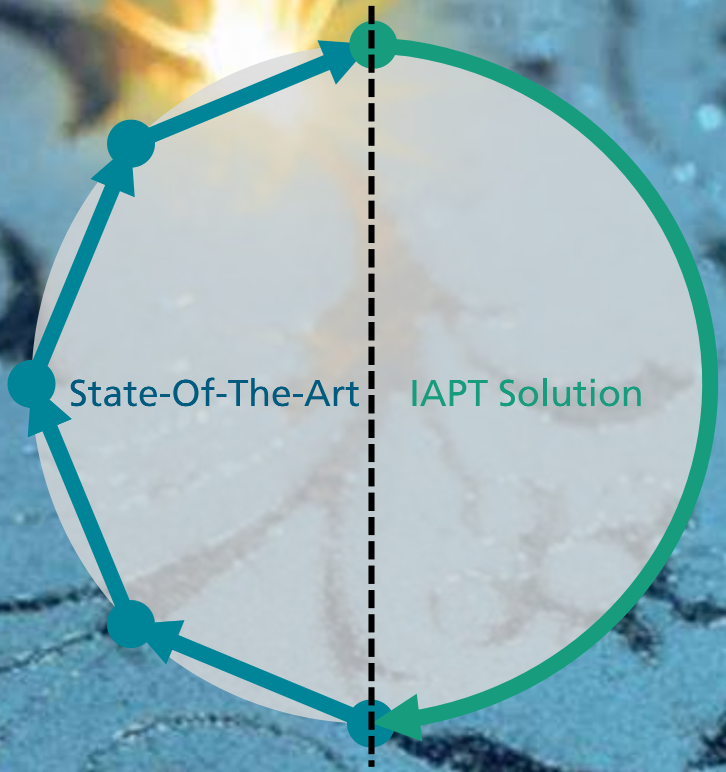

LPBF-Machine
I got the point! But do you think it's worth putting more effort into this topic?

Of course! The results are promising.

Industrial Partner
Can I join these activities?

We would be happy about it!

Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

public

Vertraulich

Fraunhofer IAPT

Fraunhofer IAPT

Maximilian Kluge, M.Sc.
Materials & Finish

Potentials and processability of recycled materials for AM

The authors

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Business Developer

Malte Becker, *M.Sc.*

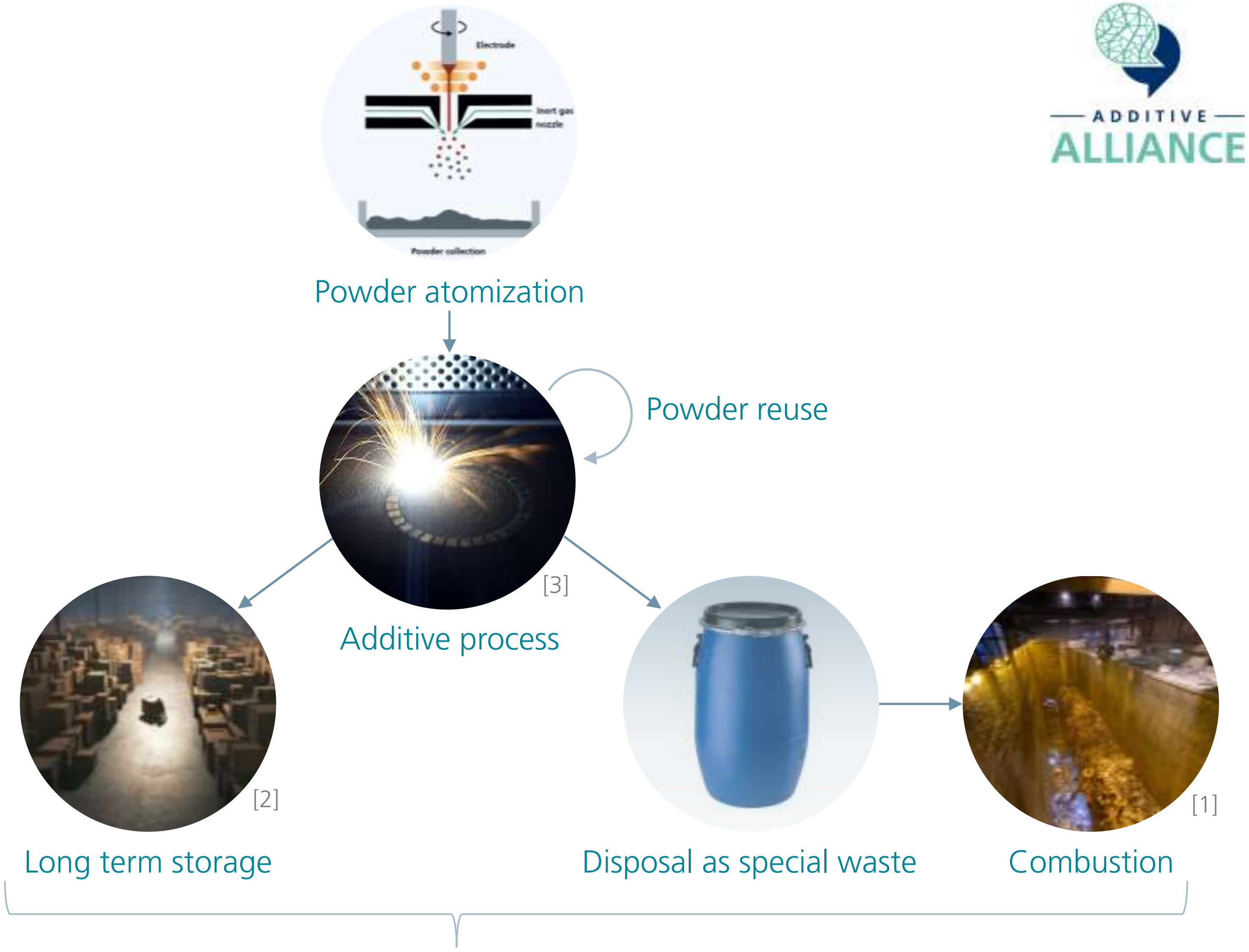
Scientist

Motivation

What is the current problem?

Situation

- Currently, powder is cost expensively atomized out of semi-finished products
- After using the powder there is no established recycling chain for a cost effective and sustainable procedure
- Often the powders are disposed via special waste or long time stored to avoid decisions



Cost and time intensive + non-sustainable process

  Vertraulich

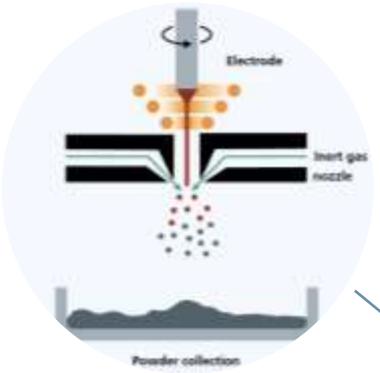
Sources:
[1] schafer-shop.de
[2] swd-ag.de
[3] Cetim → metal-am.com

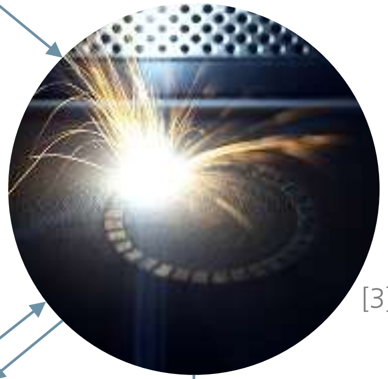
Approach

What is the solution?

Assumptions and aims

- Old powders can be re-integrated in the powder manufacturing process via re-atomizing
- Powders can be manufactured out of material waste
- Old powders can be used by other end-users with lower requirements
- Instead of disposing old materials, distribution ways can be identified to establish cost effective material chains





[3]

Recycling or re-atomising

Selling old powder to recycling companies for further processing

[4]

Secondary market

Using old or recycled powders for low-spec applications

  Vertraulich

Sources

3 Cetim → metal-am.com

4 pnas.org

Methodology

How will the deep dive look like?

Theoretical part

Market screening

- Overview of the AM material market
- State of the art powder production and material usage
- Market survey with regards to re-use and recycling

Experimental part

PRINTABILITY of recycled Ti6Al4V

Processing material made out of recycled powder for L-PBF

Significant reduction of energy consumption

Powder characterization

- Particle size distribution
- Morphology
- Flowability

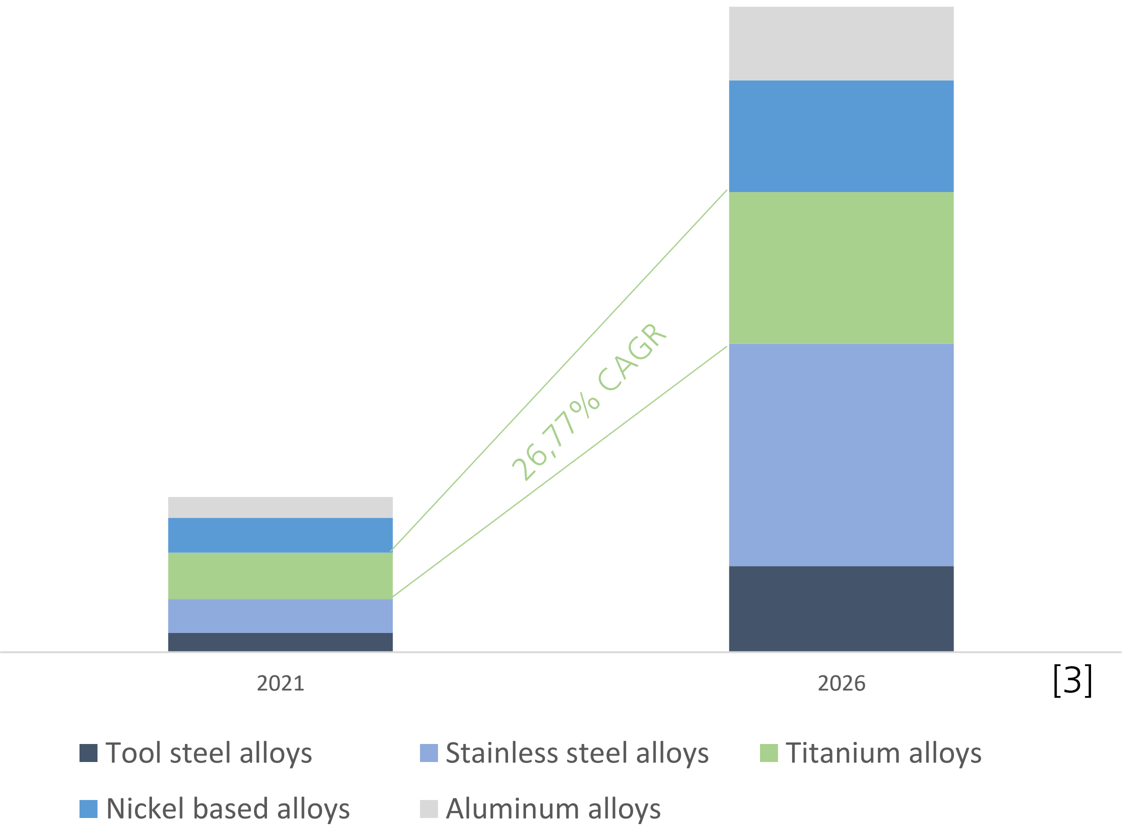
Part characterization

- Surface roughness
- Density
- Tensile properties

Theoretical part
Powder market

Market size and growth

- Global powder market is worth 8.9 billion USD in 2021[1]
- Main market demand from North America and East Asia
- Overall metal powder market shows a CAGR of 7.4% for the next 10 years[2]



[1] Persistance
[2] Smarttech
[3] AM Power

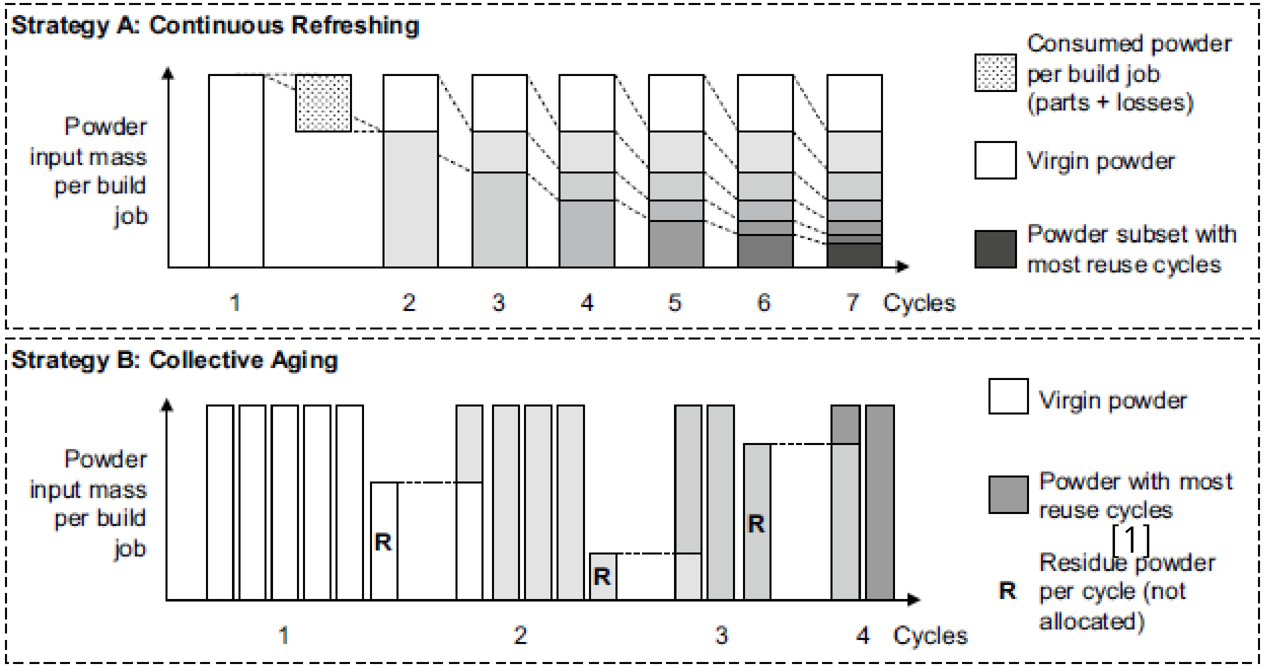
Theoretical part

Powder reuse and recycling

Powder re-use

- To increase the degree of material utilization, powder is not only processed once in many AM technologies, but is re-used several times
- There are different ways of recycling
- Common procedure

Re-use strategies



[1] Lutter-Günther, M.:Powder recycling […], 2018, Production Engineering

Theoretical part
Powder reuse and recycling

Powder recycling

- More and more companies are founded addressing the topic of titanium powder and scrap material recycling
- Companies are addressing close loop material chains where old powders and other residuals can be reintegrated into the process chain
- Major reduction of energy consumption around 89-99% (Co2 equivalent)
- Also sale strategies, like discount when reselling old powders are already offered by companies

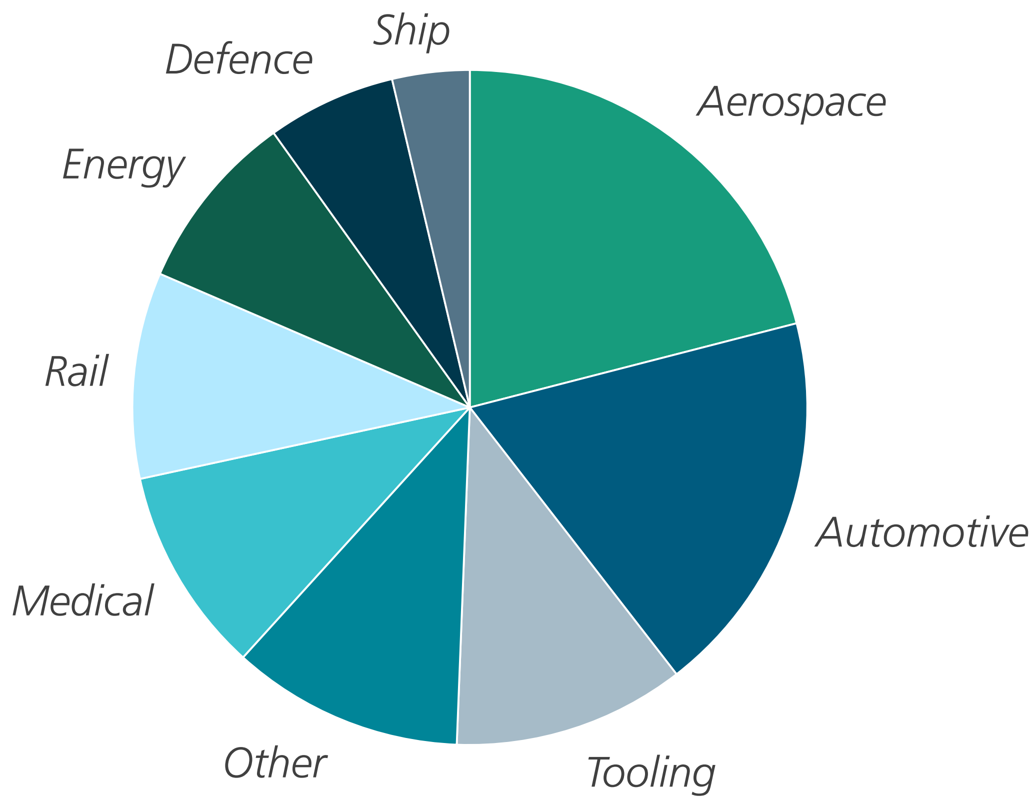
[1]

Demonstration facility for the production of recycled titanium powder in Halifax (capital investments of over 82,1 Mio. $)

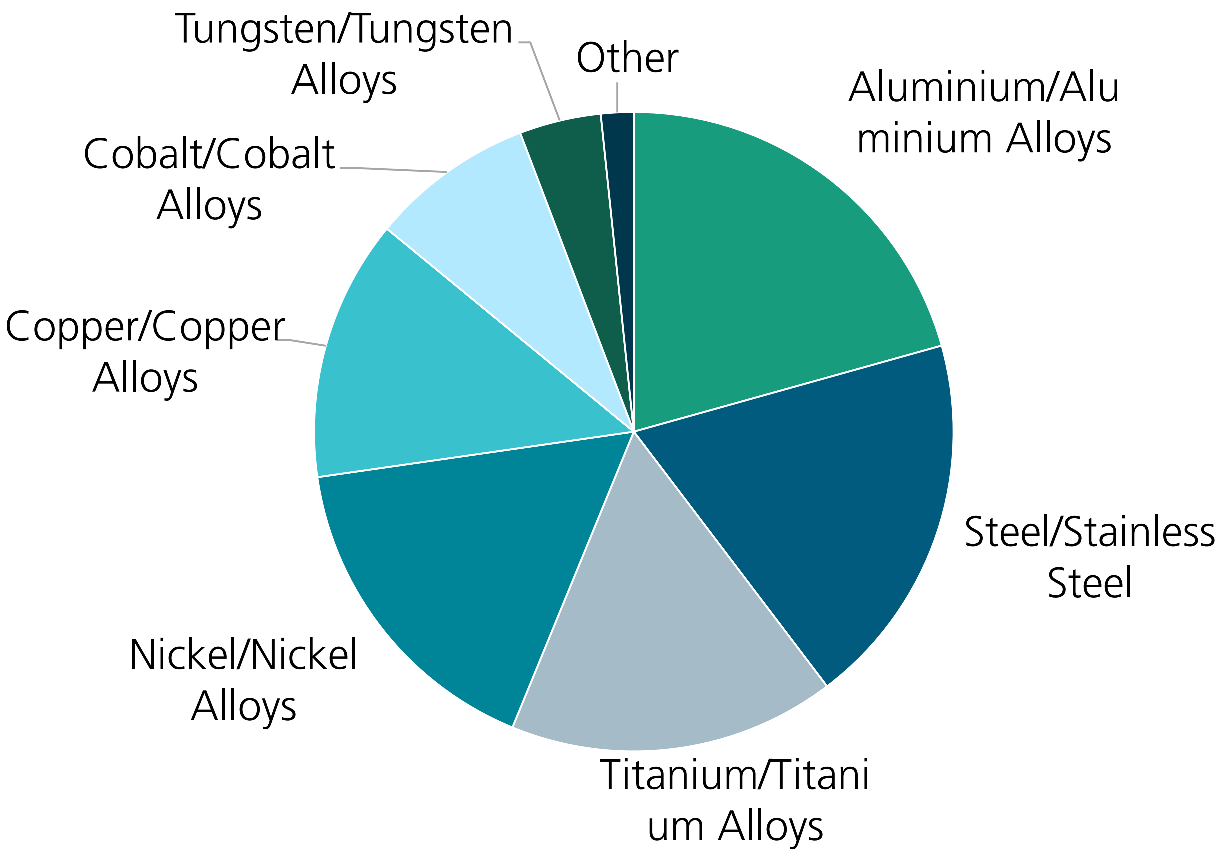
1IperionX

Theoretical part
Survey participants

Branche affiliation



Materials used



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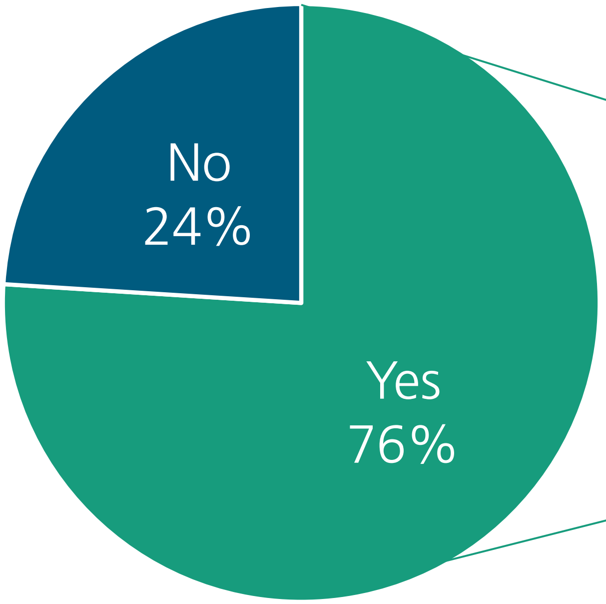
Theoretical part

Survey - questionnaire

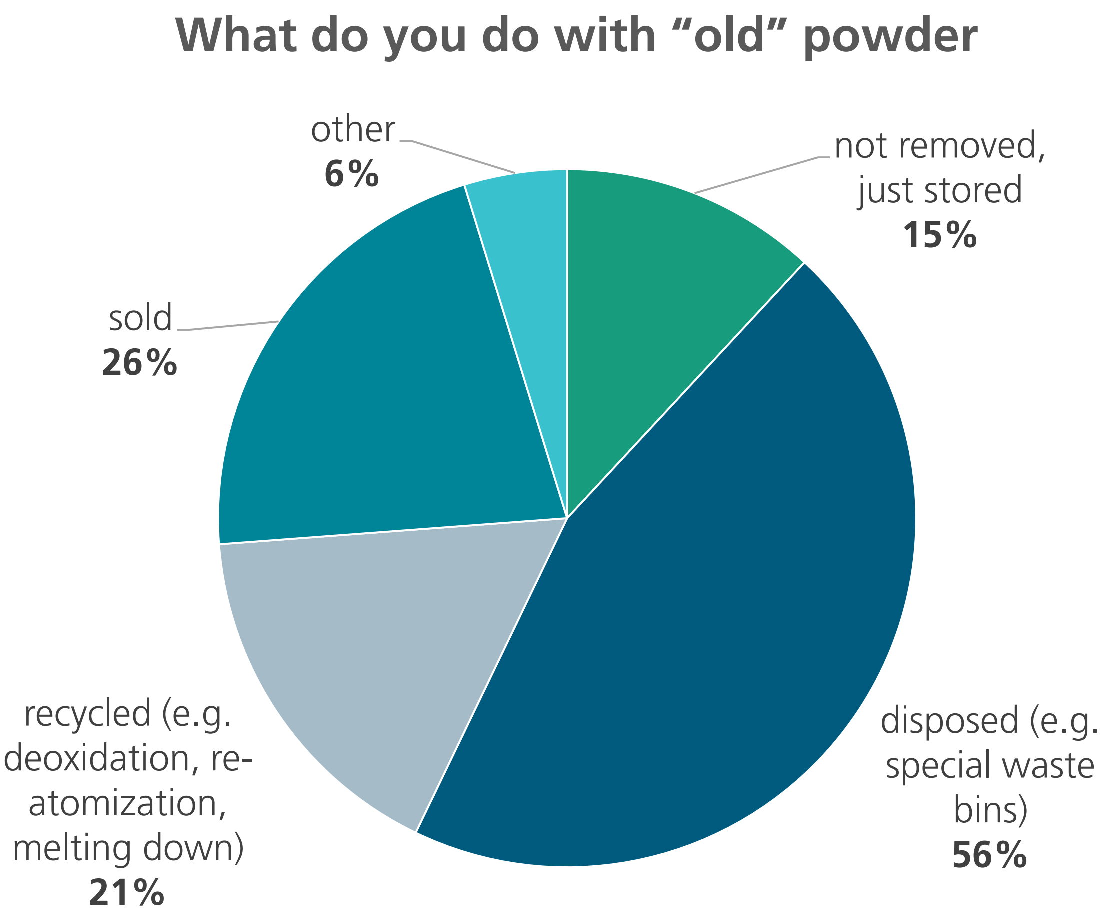
Do you re-use powder?



- 88 % are refreshing with virgin powder
- 20% re-use but do not mix batches
- Only 21% use their powder more than 15 cycles

Theoretical part

Survey - questionnaire

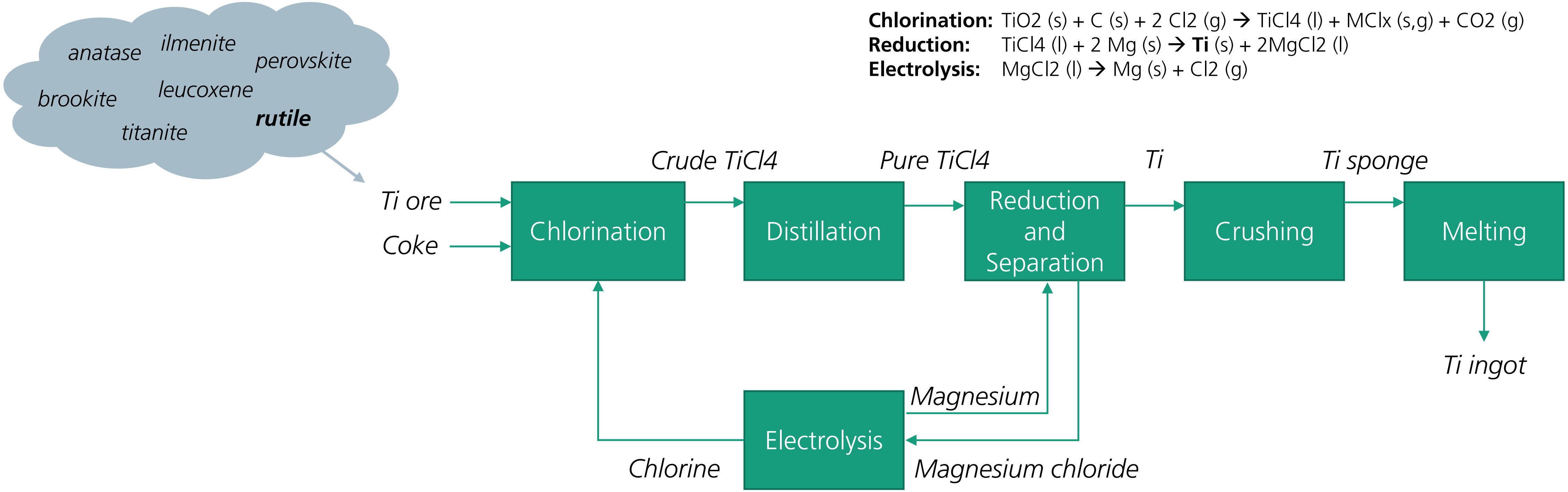


- 71% of the participants are at least partly storing or disposing their old powders
- Main problems for powder removal was due to the high costs and the lack of storage capacaties

Theoretical part
Powder consumption

Titanium production

Chlorination: TiO_2 (s) + C (s) + 2 Cl_2 (g) → $TiCl_4$ (l) + MCl_x (s,g) + CO_2 (g)
Reduction: $TiCl_4$ (l) + 2 Mg (s) → **Ti** (s) + 2$MgCl_2$ (l)
Electrolysis: $MgCl_2$ (l) → Mg (s) + Cl_2 (g)

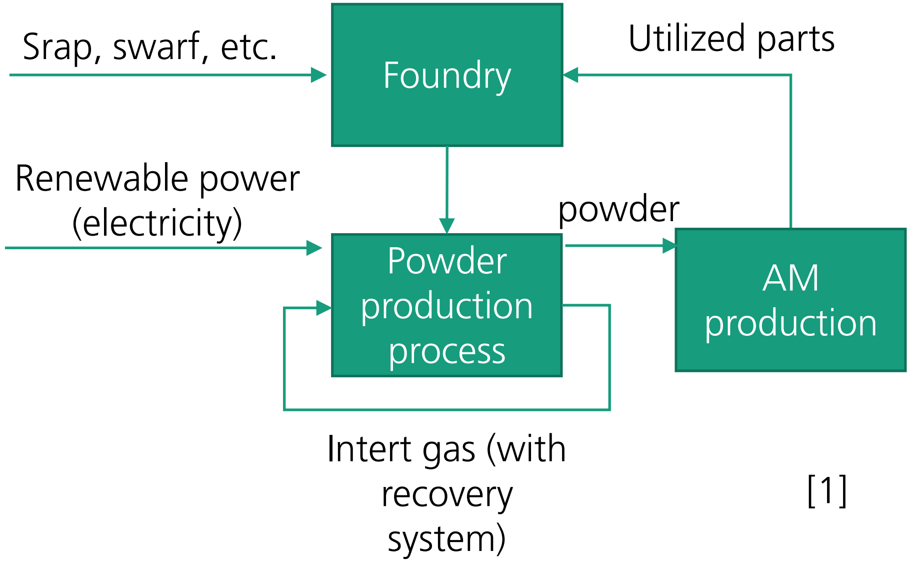


Theoretical part
Used material and powder production method

Powder production

- Commercially available powder is normally produced by plasma and gas-based atomization processes using thin wires and ingot as feedstock material
- The study powder was produced out of >98% of recycled Ti64 (compacts) and aluminum foil
- Compacts are made out of turnings, swarf and ships and were processed threw a foundry and a inert gas based powder production system
- Method claims to have an energy saving of at least 89% compared to traditional powder

Powder production method of study feedstock



[1]

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  Vertraulich

Practical part

Powder characterization

Investigated powder

- Ti6Al4V (grade 5)
- PSD of 20–63 µm
- Puchased for ~180 €/kg

Chemical composition was within the specification

Chemical Composition				
Element	Specification[1] (wt. %)		Measured[2] (wt. %)	Method
	Min.	Max.		
Al	6.00	6.75	6.26	ICP-OES
C	-	0.08	0.007	Combustion
Cu	-	0.10	<0.01	ICP-OES
Fe	-	0.30	0.15	ICP-OES
H	-	0.03	0.0028	ICP-OES
N	-	0.03	0.0065	Inert Gas Fusion
O	0.11	0.16	0.1449	Inert Gas Fusion
Y	-	0.005	<0.005	ICP-OES
Sn	-	0.10	<0.01	ICP-OES
Ti	Rem.	Rem.	Rem.	ICP-OES
V	3.5	4.5	4.36	ICP-OES
OE, Each	-	0.1	<0.10	ICP-OES
OE, Total	-	0.40	<0.40	ICP-OES

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Practical part
Powder characterization

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- Ti6Al4V (grade 5)
- PSD of 20–63 µm
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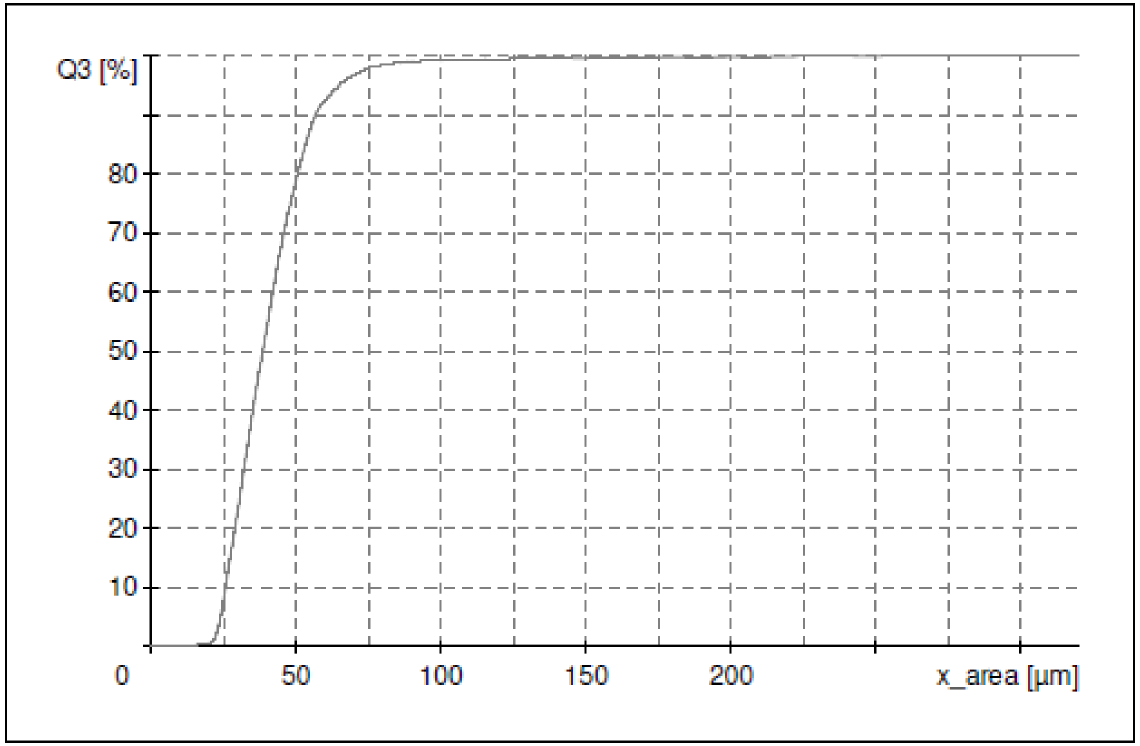
PSD was within the specification

Camsizer – Measurement of particle size distribution



Kenngrößen

Q3 [%]	x [µm]
10.0	25.6
50.0	38.5
90.0	56.7

x [µm]	Q3 [%]
1000.0	100.0
2000.0	100.0
4000.0	100.0

SPAN3 =	0.808
U3 =	1.635

Practical part

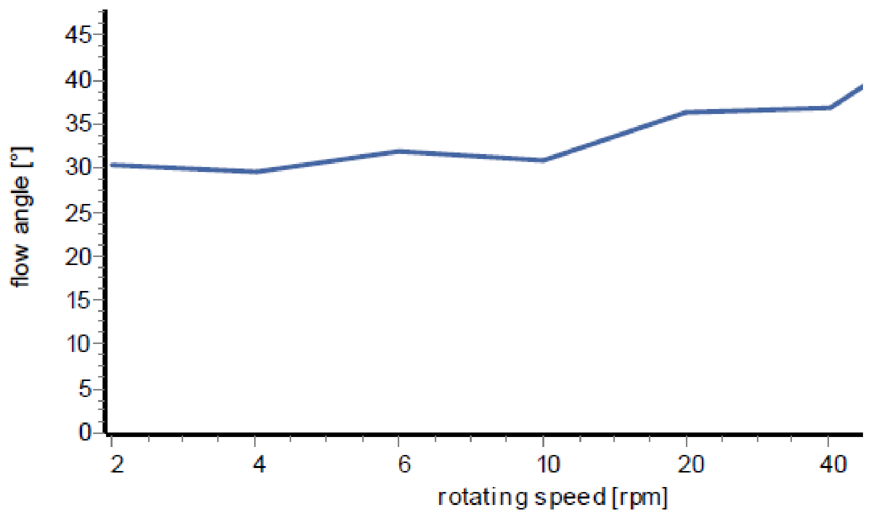
Powder characterization

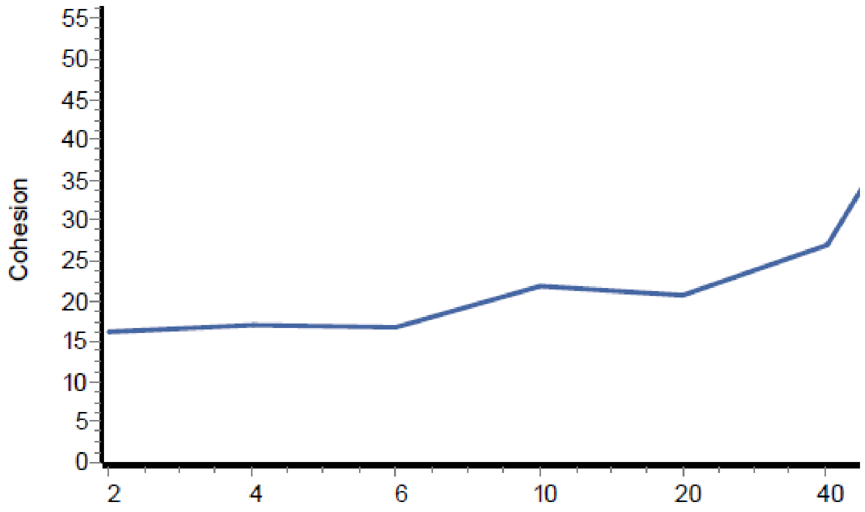
Investigated powder

- Ti6Al4V (grade 5)
- PSD of 20–63 µm
- Puchased for ~180 €/kg

PSD was within the specification

Granudrum – Measurement of rheological characteristics





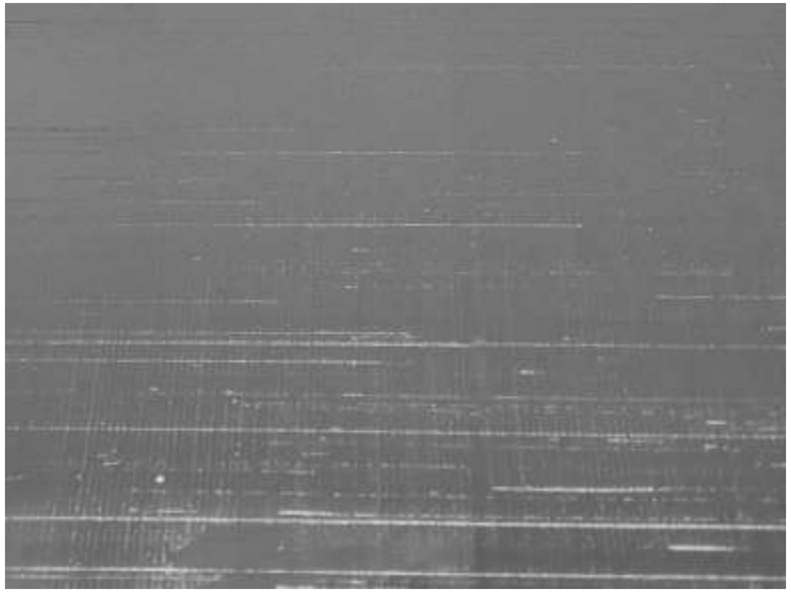
Practical part

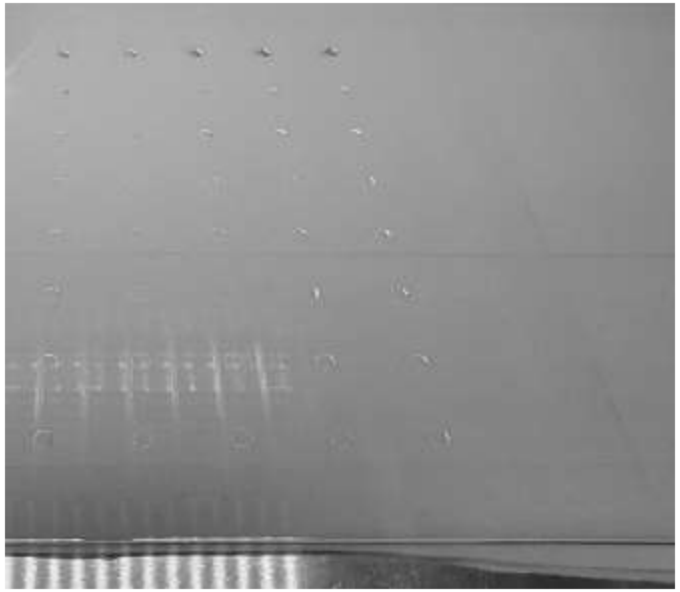
Printability of recycled powder

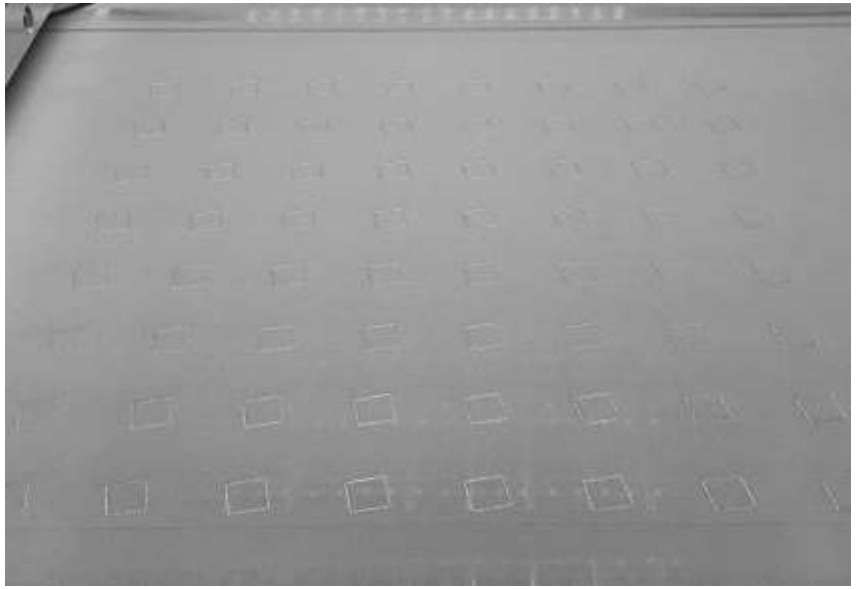
Parameter study

- Investigations were carried out on an 3D Systems DMP 350 machine
- Mainly laser power, scanning speed and hatch distance were varied

First build job







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Practical part

Printability of recycled powder

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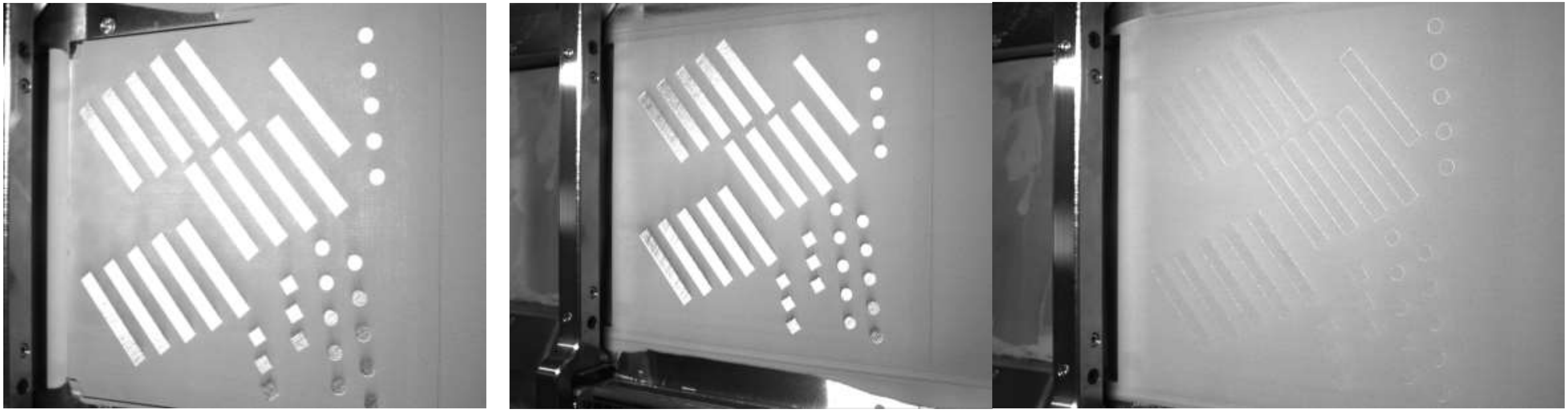
Following build jobs



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Practical part

Printability of recycled powder

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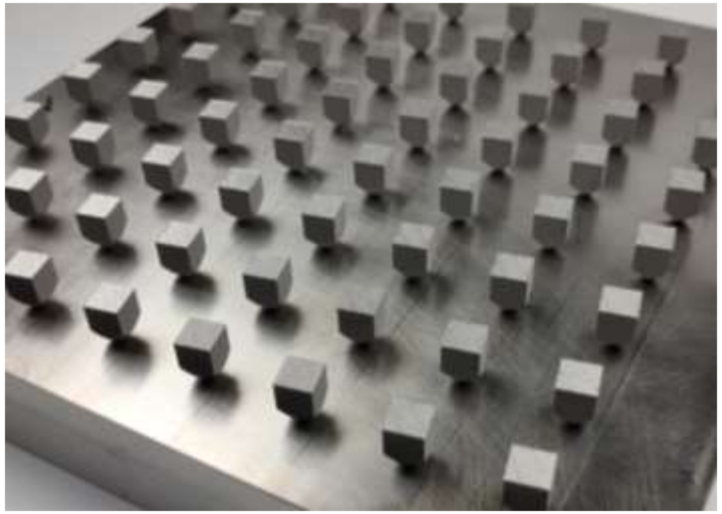
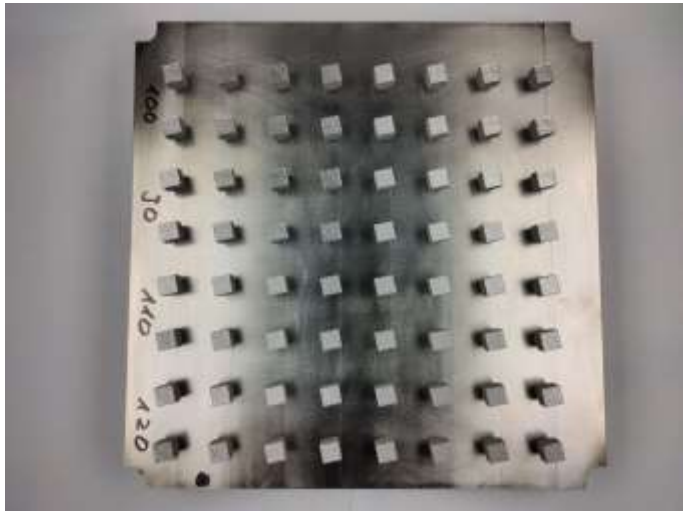
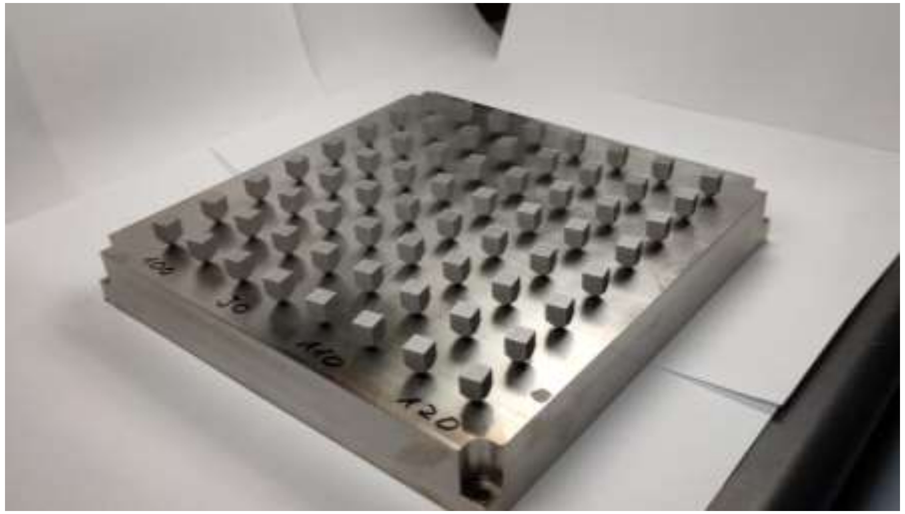
Build Jobs







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Practical part

Printability of recycled powder

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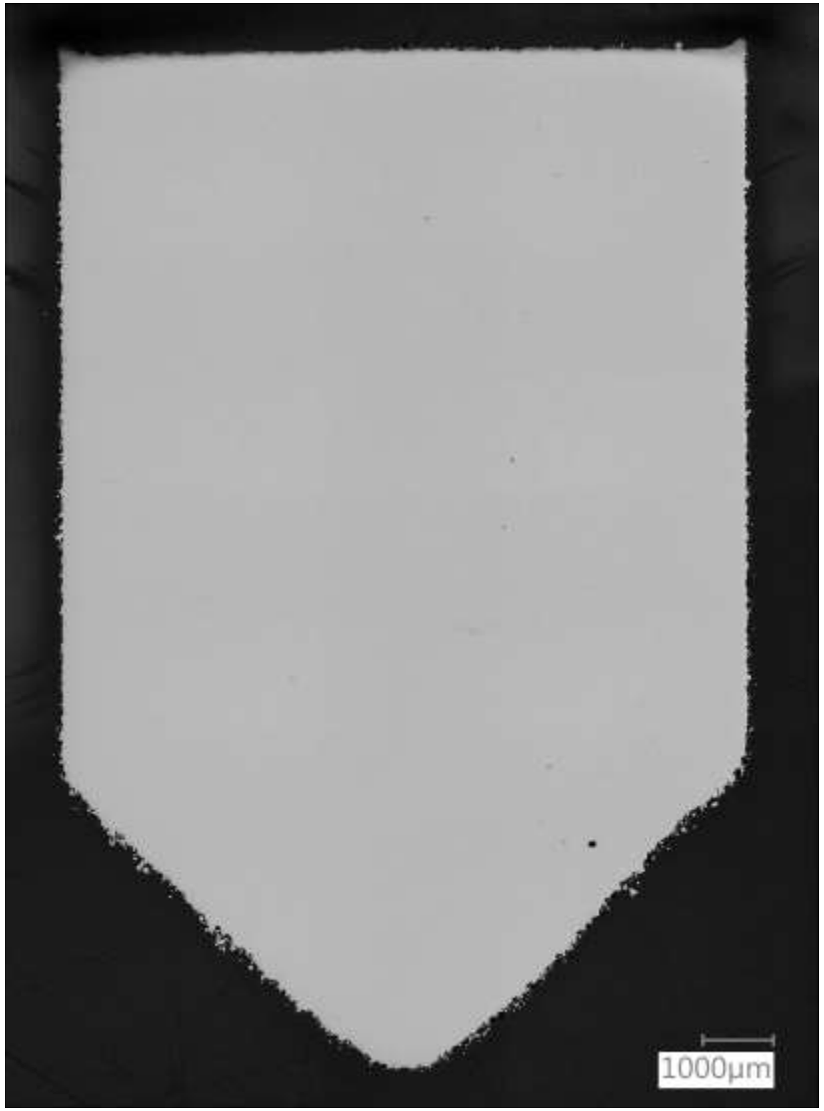
PARAMETER	VALUE
Layer thickness [µm]	30
Laser power [W]	160
Scanning speed [mm/s]	1,100
Hatch distance [µm]	100
Built rate [cm³/h]	11,88

Reaching density of **> 99,9%**



Practical part

Printability of recycled powder

Parameter study

- Investigations were carried out on an 3D Systems DMP 350 machine
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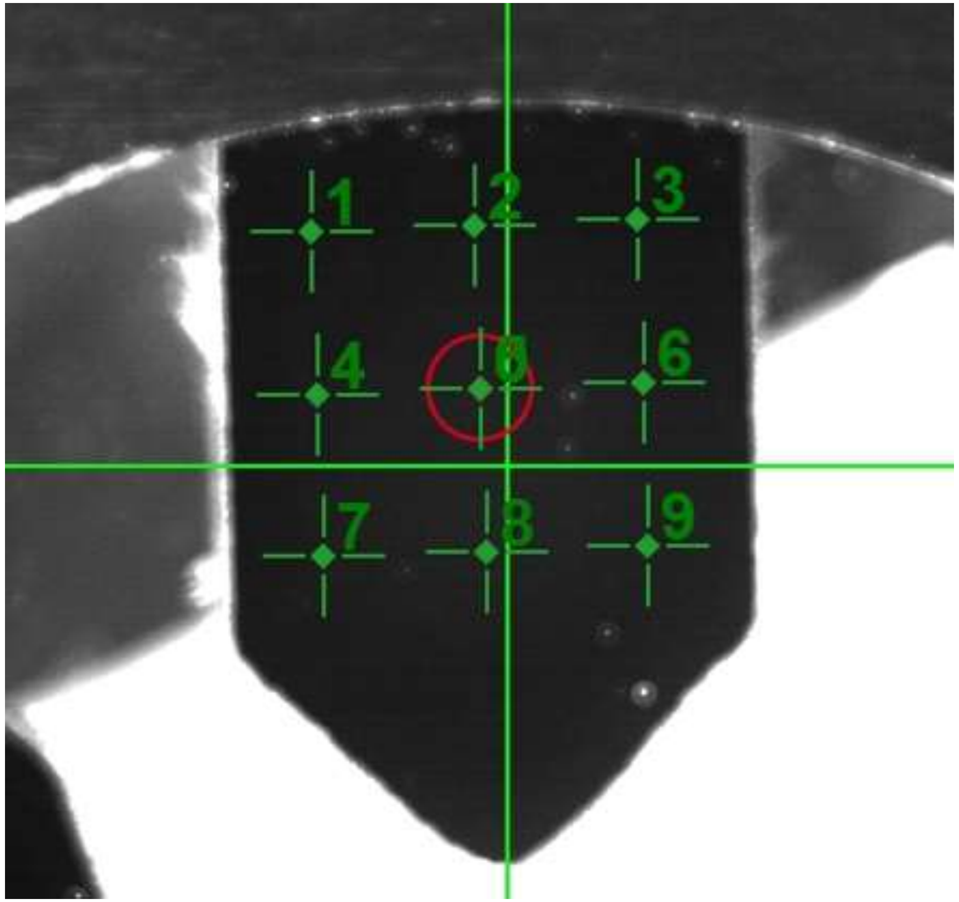
Results	
HV 10	Standard deviation
355	6,635

Hardness



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Practical part

Printability of recycled powder

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- Mainly laser power, scanning speed and hatch distance were varied

Roughness 0°

Sa	Standard deviation	Sz	Standard deviation
4,69 µm	0,49 µm	75,34 µm	6,7 µm

Roughness 90°

Sa	Standard deviation	Sz	Standard deviation
12,67 µm	0,81 µm	104,35 µm	12,5 µm

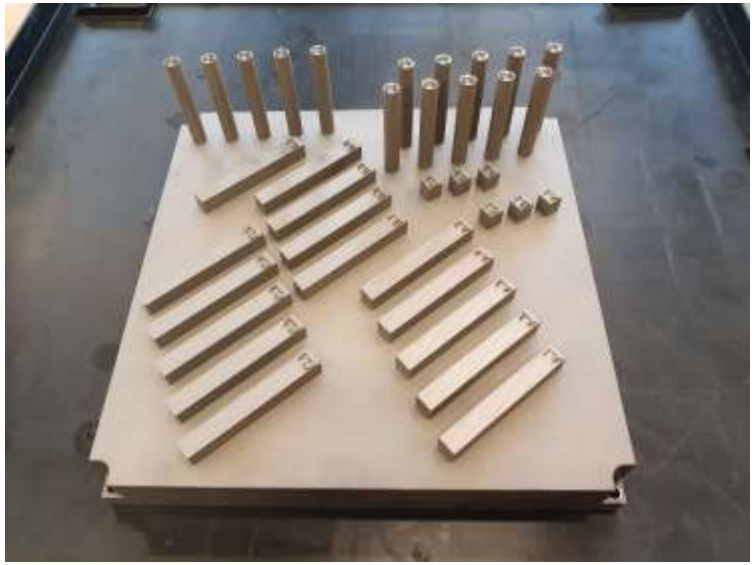
Practical part

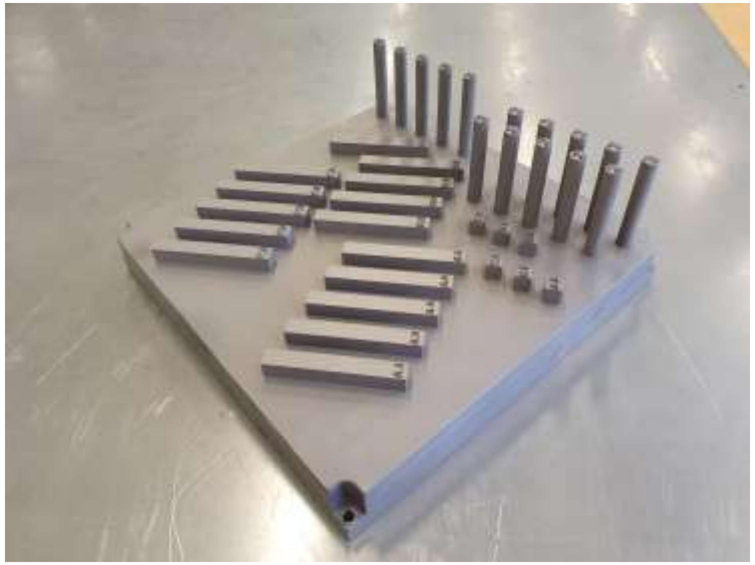
Printability of recycled powder

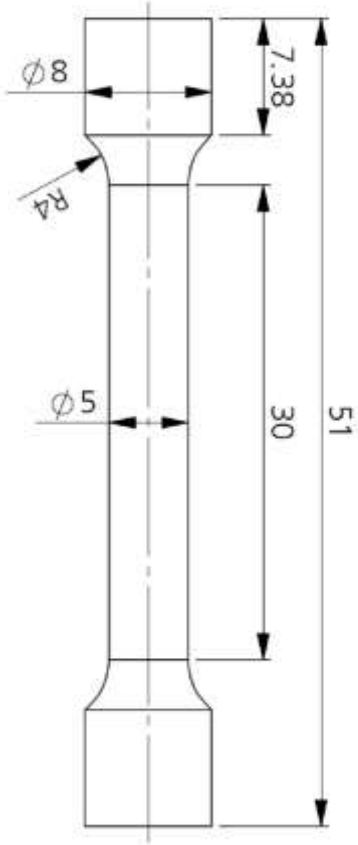
Printing of tensile specimens

- Printing of 30 Tensile specimens
- Heat treated at 800 °C for 2 hours before being separated from the build plate by wire cut eroding EDM and testing of 10 specimens

Final specimens







Form B d_0 = 5 mm according to DIN 50125

1MollyWorks Materials PTE LTD

Conclusion

Powder characteristics

- Powder within the specification
- Irregularities inside the powder bed in first build job – disappeared after sieving
- Much lower energy consumption (-90% Co2 eqv.)

Printability

- Density of > 99,9 % achieved
- Comparable hardness and good surface roughness

Outlook

- High potentials for cost reduction in close loop cycles
- Rising market and possibilities for recycling and/ or reselling powder

Maximilian Kluge, M.Sc.
Head of Materials & Finish

Potentials and processability of recycled materials for AM

Thank you for you attention!

Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

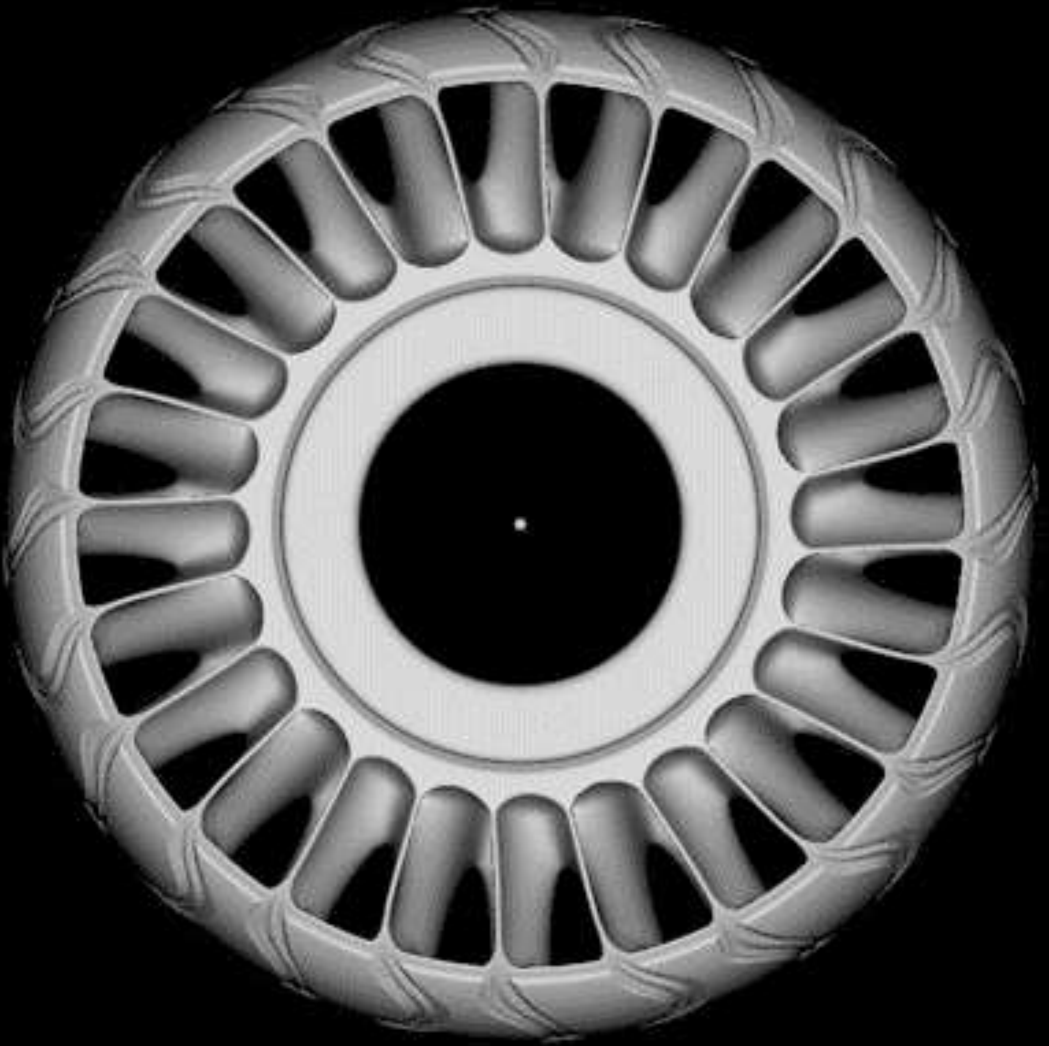
DAY 1

DAY 2

Design Automation and Beyond

Guenael Morvan

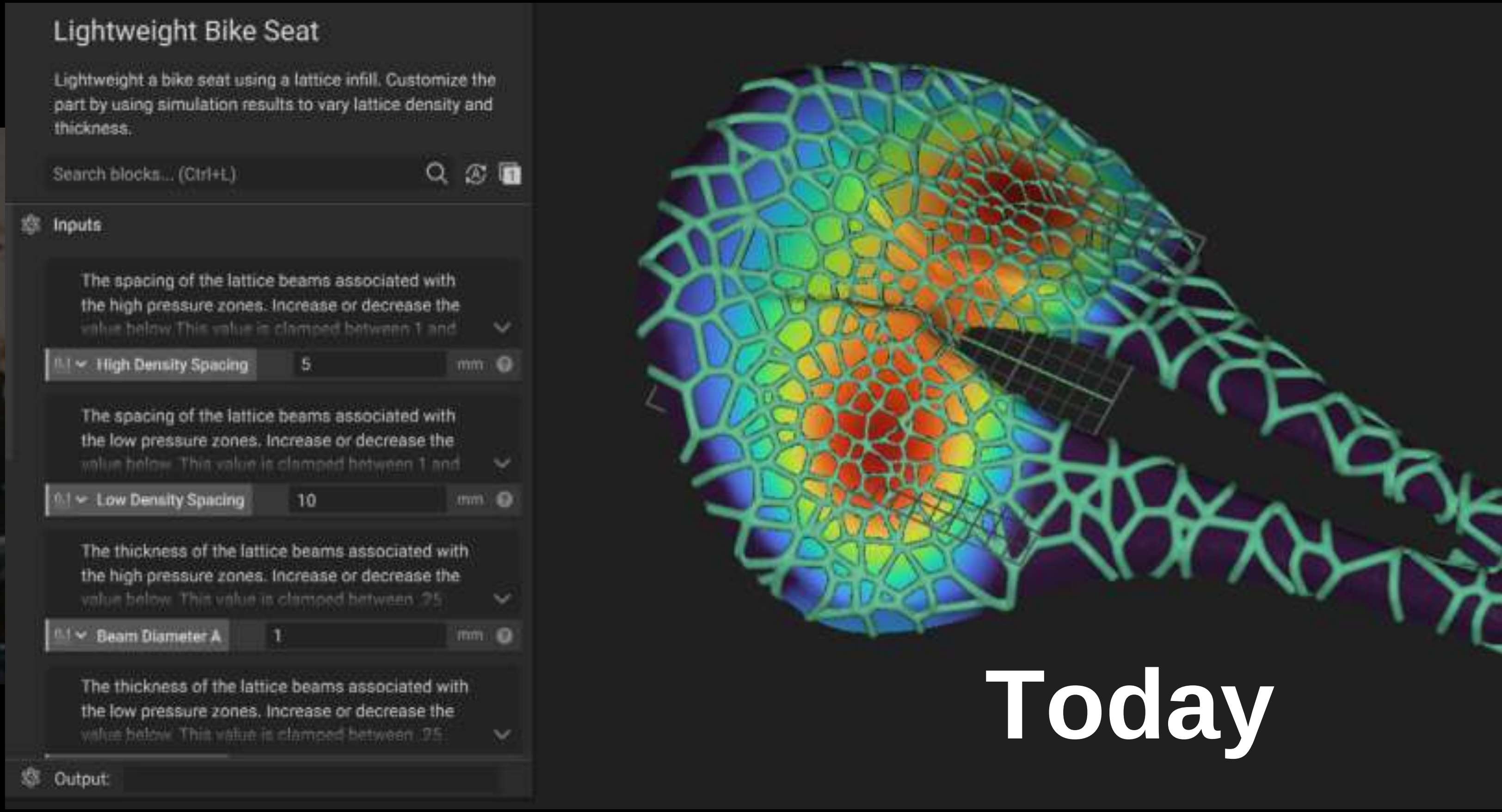
Application Engineer



nTopology

Manufacturing has advanced.

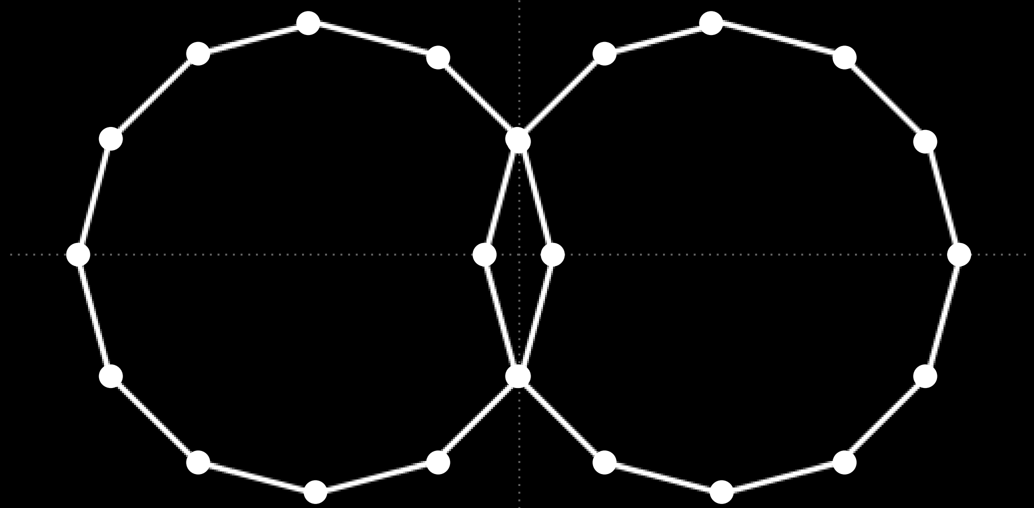
It’s time our design tools did too.



Design Without Boundaries. Literally…

Complicated

Legacy Boundary Representation



$$A(R',d') = R'^2 \cos^{-1}\left(\frac{d'}{R'}\right) - d'\sqrt{R'^2 - d'^2}$$

$$d_1 = x = \frac{d^2 - r^2 + R^2}{2d}$$

$$d_2 = d - x = \frac{d^2 + r^2 - R^2}{2d}$$

$$A = A(R, d_1) + A(r, d_2)$$

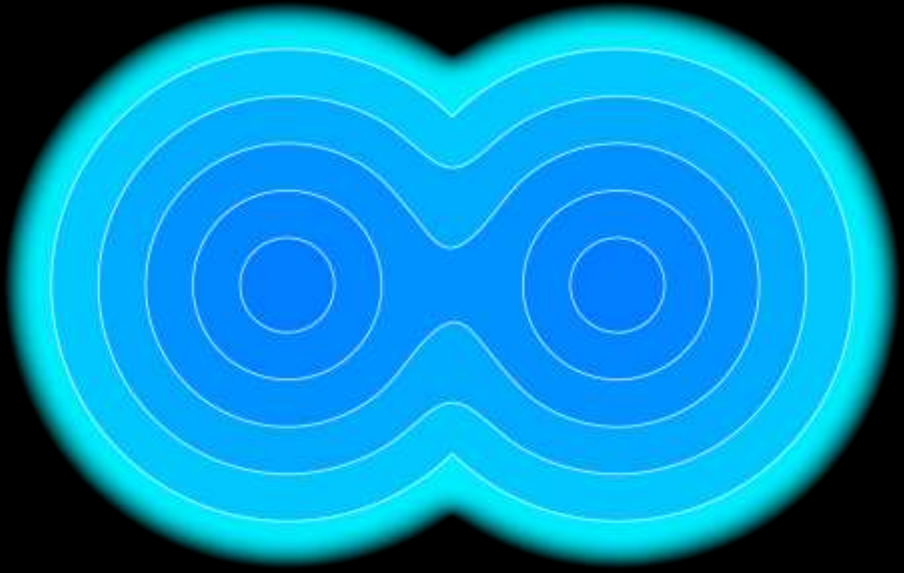
$$= \frac{r^2 \cos^{-1}\left(\frac{d^2+r^2-R^2}{2dr}\right) + R^2 \cos^{-1}\left(\frac{d^2+R^2-r^2}{2dR}\right) -}{\frac{1}{2}\sqrt{(-d+r+R)(d+r-R)(d-r+R)(d+r+R)}}$$

$$A = 2R^2 \cos^{-1}\left(\frac{d}{2R}\right) - \frac{1}{2}d\sqrt{4R^2 - d^2}$$

$$= 2A\left(\frac{1}{2}d, R\right)$$

Simple

nTop Implicit Representation

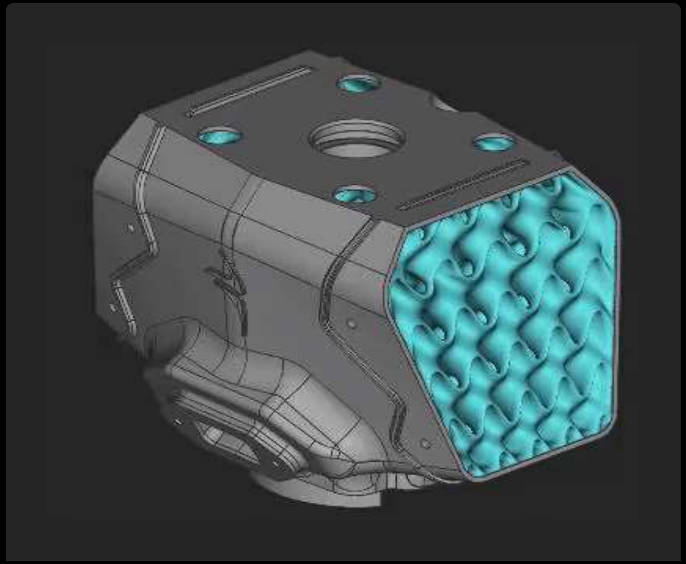


$$f(x,y) = min(CircleA, CircleB)$$

Our Core Tech Differentiators

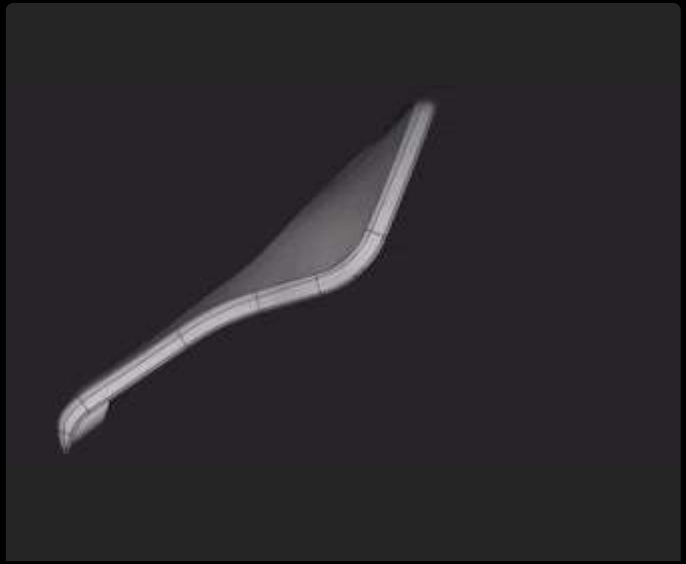
Implicit Modeling

A fundamentally different and unbreakable modeling technology that delivers unprecedented speed, scalability, and reliability.



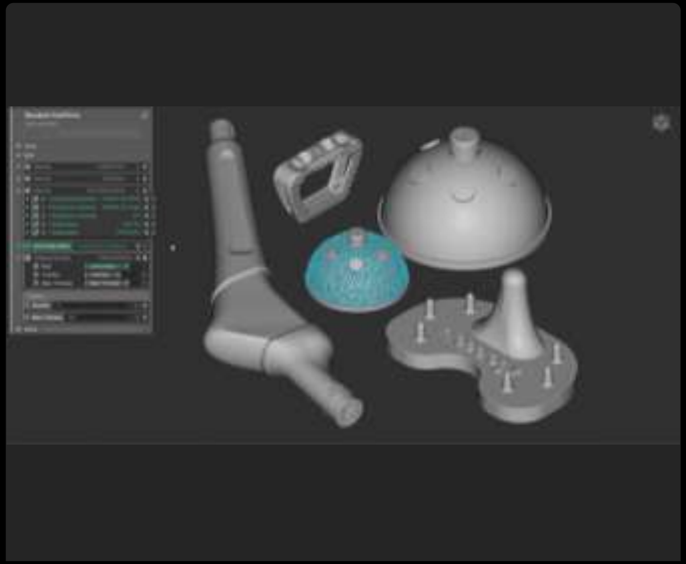
Field-Driven Design

A new design approach that enables you to control parameters at every point directly from simulations, test data, and engineering formulas.



Blocks & Codeless Automation

A block-based approach to design automation that allows you to reuse workflows, speed up design iterations, and package engineering processes.

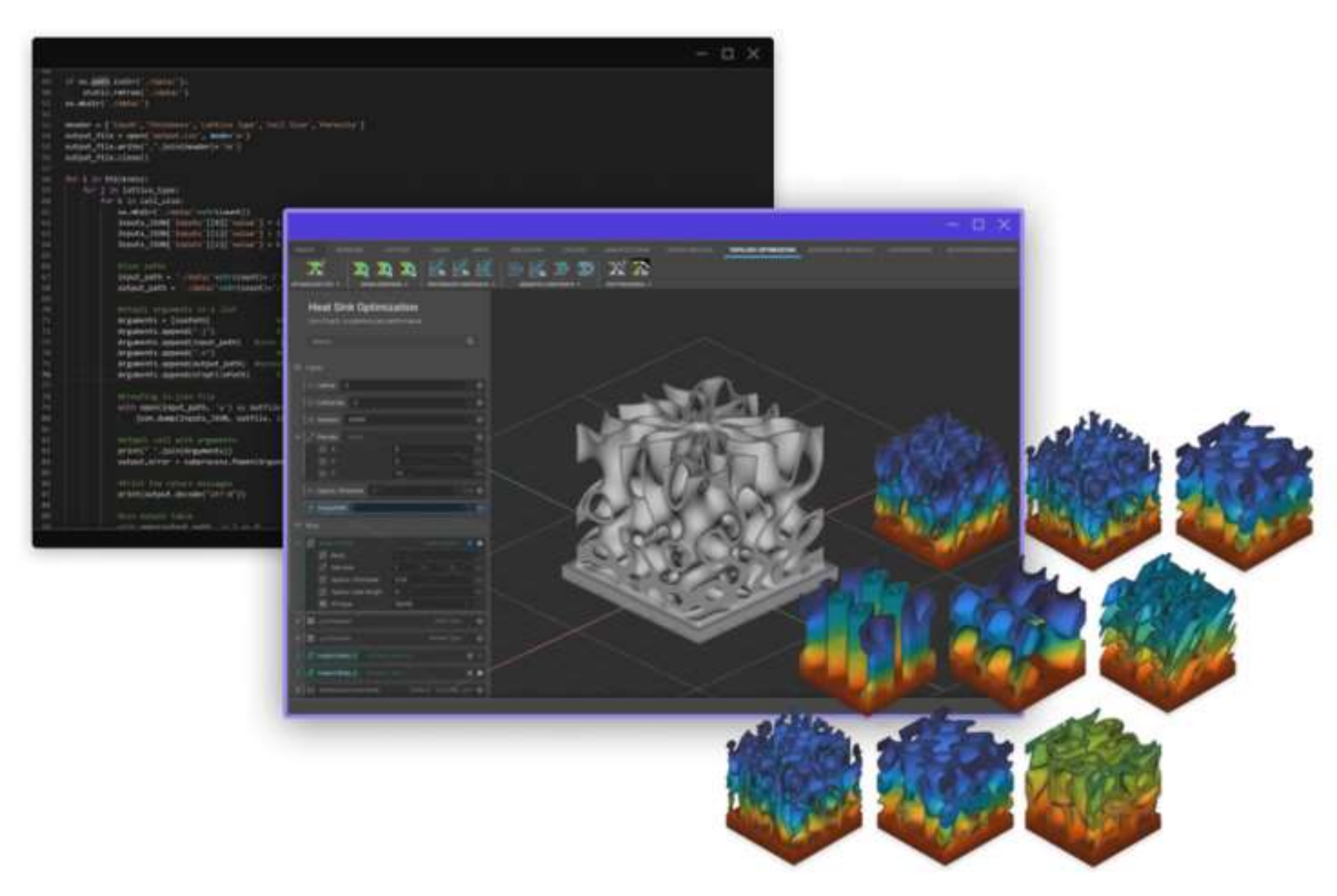


We enable you to automate & scale

Headlessly execute nTop workflows with **nTopCL**, our command line interface

Write scripts for **batch processing** or **mass customization**

Create computational **Design of Experiments** (DoEs) for design optimization or connect nTopology to **MDO** tools



nTopCL Process

Find nTop Workflow → *Define Input & Output* → *Scale up with nTopCL*

Find the nTop workflow that can solve your problems:

- *Topology Optimization*
- *Lattice Generation*
- *Shelling*
- *Meshing*
- *AM Build Prep*

Define your input and output variables that will be replaced for each headless execution of your nTop workflow.

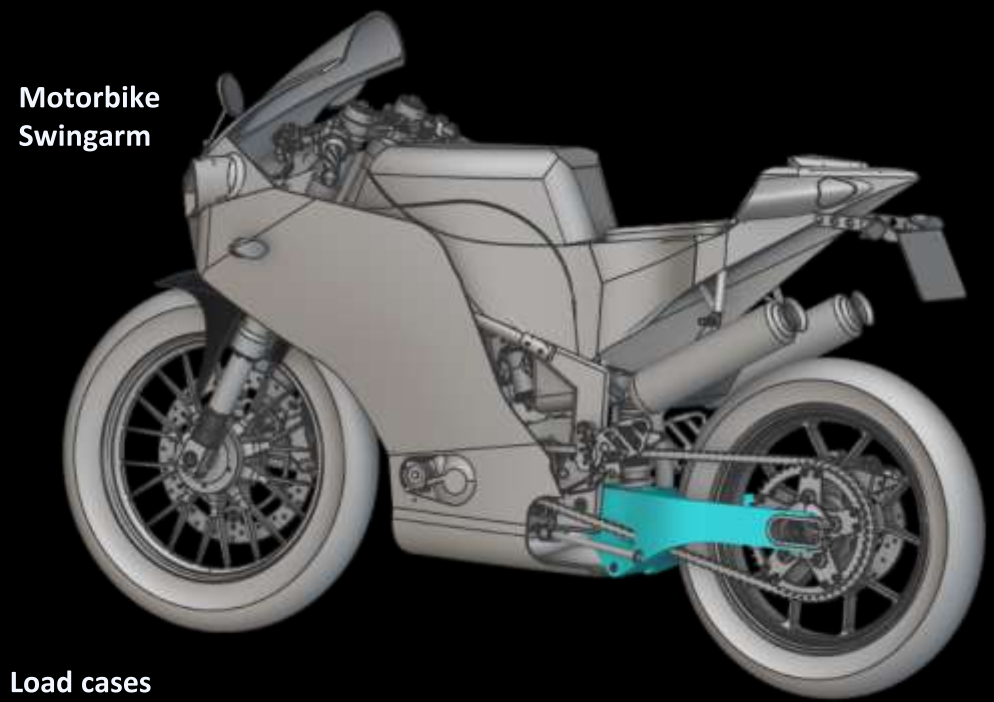
nTopCL can generate the input and output templates for you.

Execute nTopCL from apps or scripts written in Python, Matlab, etc.

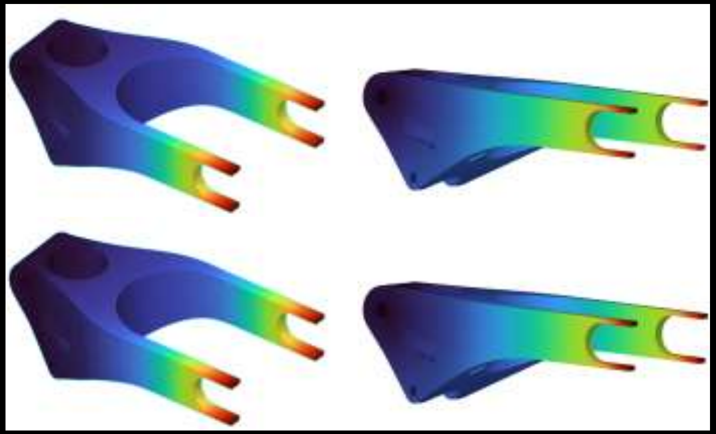
Use Multidisciplinary Design Optimization (MDO) softwares for enhanced design optimization and analysis experience.

ModeFrontier will be used for today's Demo!

Motorbike Swingarm Lightweighting

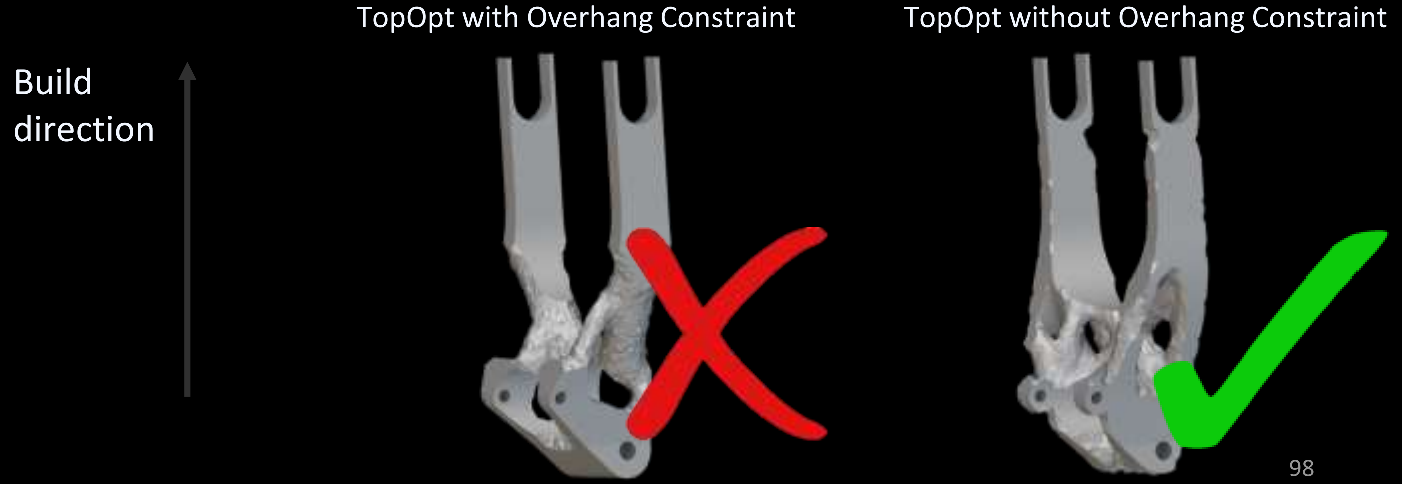


Load cases



Topology Optimization VS **Top Opt + Field-driven design**

- **Top Opt** Result performance may highly depend on top opt parameters such as Boundary Penalty, Volume Fraction or density threshold
  - **To make sure it's a fair comparison, a DoE to choose the best Top Opt has been done**
- **Top Opt + Field-driven design** will include variable shelling and thickness re-adjustment
- Focus for comparison is on structural performance
- However, manufacturability metrics will also be considered
- Since main focus is structural performance, topology optimization using **overhang constraints will be discarded**, since it improves support volume requirements but decreases overall structural performance

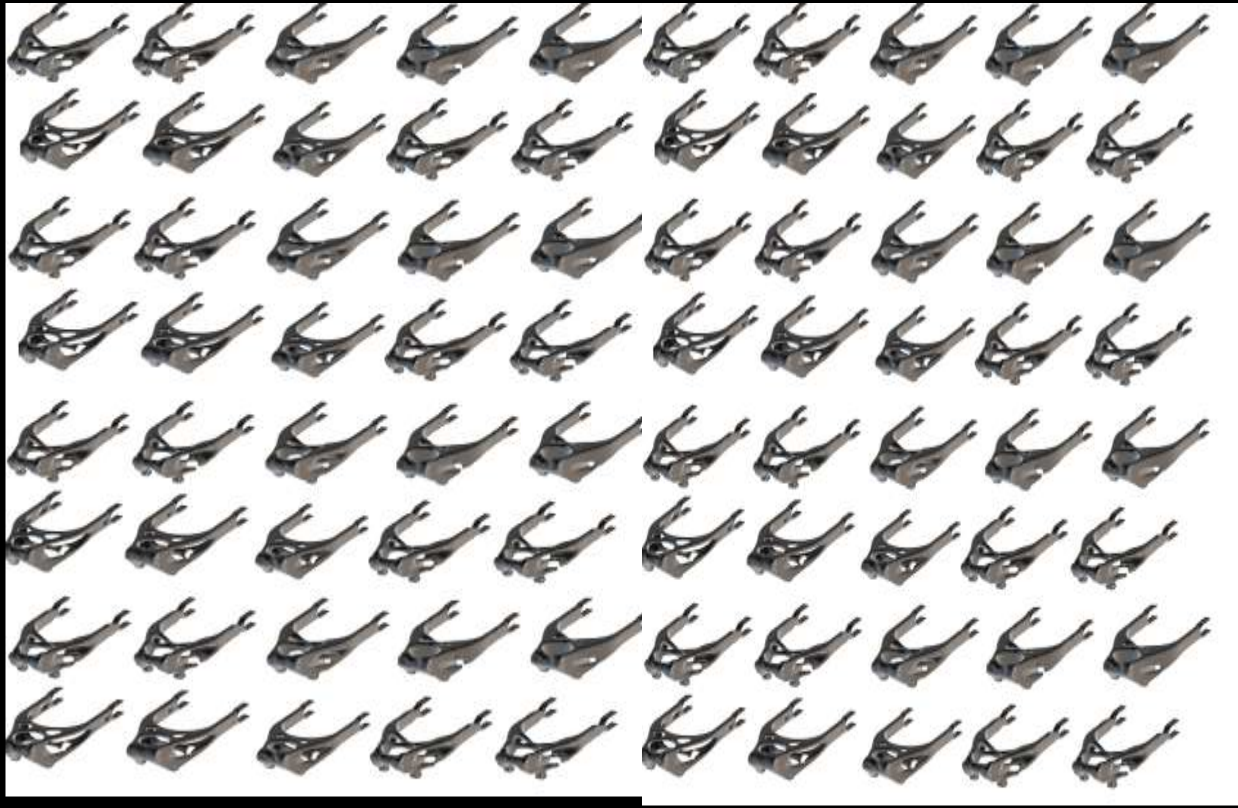


nTopology

Best TopOpt VS TopOpt + Field-Driven Design

Best TopOpt Result

from a **Generative Design** full factorial experiment or DOE with 90 different combinations of BP, VF & Th* **using nTop CL**



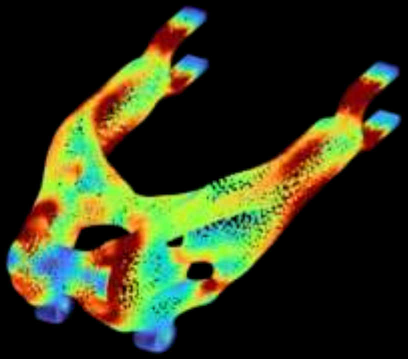
* BP = Boundary Penalty
VF = Volume Fraction
Th = Threshold Value

```
Threshold = [0.1, 0.15, 0.2, 0.25, 0.3, 0.5]
Boundary_Penalty = [0.0, 0.25, 0.5, 0.75, 1]
Volume_Fraction = [0.3, 0.5, 0.7]
```

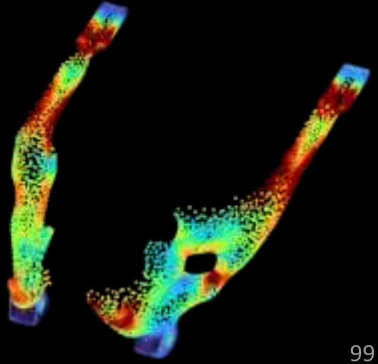
Combination

TopOpt Result + field-driven design lightweighting techniques

Thickness readjustment



Variable Shelling

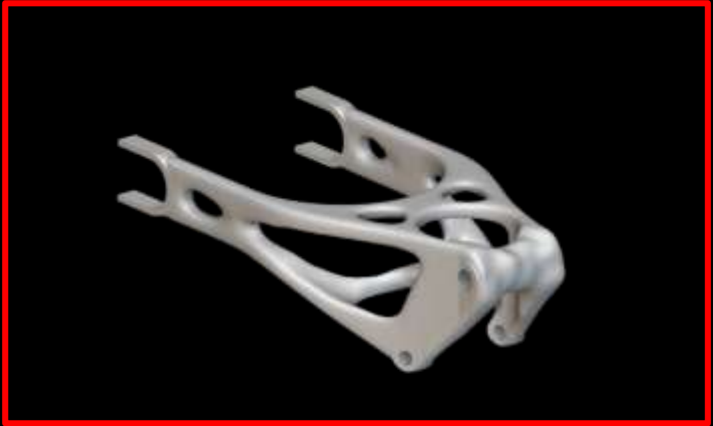


nTopology

Selection of Best Top Opt Result for Benchmark

Iteratio Numbe	Thresh Value	Bound Penalty	Volume Fractio	LC1 Ma Stress	LC1 Ma Displ (	LC2 M Stress	LC2 M Displ (	LC3 M Stress	LC3 M Displ (	LC4 M Stress	LC4 M Displ (	Weight Saving
1	0.1	0	0.3	19.31	0.40	34.96	0.54	27.40	0.48	28.18	0.48	44.32
2	0.1	0	0.5	11.30	0.35	20.16	0.48	11.11	0.36	11.32	0.36	28.15
3	0.1	0	0.7	8.76	0.33	12.24	0.44	8.14	0.33	8.14	0.33	11.92
4	0.1	0.25	0.3	12.96	0.36	18.62	0.49	7.99	0.38	8.00	0.38	35.39
5	0.1	0.25	0.5	9.10	0.34	12.33	0.45	8.17	0.34	8.17	0.34	14.60
6	0.1	0.25	0.7	7.89	0.34	10.80	0.45	7.96	0.33	7.96	0.33	4.54
7	0.1	0.5	0.3	11.08	0.36	14.99	0.48	8.44	0.36	8.44	0.36	30.39
8	0.1	0.5	0.5	7.71	0.32	10.47	0.45	8.30	0.33	8.30	0.33	10.09
9	0.1	0.5	0.7	8.40	0.33	11.46	0.45	8.39	0.33	8.39	0.33	3.79
10	0.1	0.75	0.3	8.35	0.34	11.46	0.46	8.22	0.36	8.22	0.36	26.60
11	0.1	0.75	0.5	8.41	0.32	11.67	0.44	7.83	0.33	7.83	0.33	6.95
12	0.1	0.75	0.7	7.88	0.35	10.88	0.46	8.10	0.33	8.10	0.33	3.92
13	0.1	1	0.3	8.67	0.35	11.32	0.48	7.91	0.35	7.91	0.35	25.52
14	0.1	1	0.5	19.47	0.34	27.83	0.46	9.01	0.34	9.01	0.34	4.85
15	0.1	1	0.7	13.92	0.33	19.82	0.45	8.60	0.33	8.60	0.33	4.41
16	0.15	0	0.3	40.04	0.46	49.82	0.61	31.96	0.57	32.91	0.58	51.61
17	0.15	0	0.5	14.09	0.38	24.94	0.50	13.46	0.38	13.83	0.38	33.44
18	0.15	0	0.7	8.85	0.34	12.25	0.46	8.31	0.33	8.31	0.33	15.48
19	0.15	0.25	0.3	15.30	0.38	22.35	0.52	8.38	0.41	8.38	0.41	42.44
20	0.15	0.25	0.5	8.75	0.35	11.72	0.45	8.07	0.34	8.07	0.34	17.80
21	0.15	0.25	0.7	8.05	0.33	11.00	0.44	8.32	0.33	8.32	0.33	5.06
22	0.15	0.5	0.3	9.18	0.37	12.25	0.49	8.23	0.37	8.23	0.38	36.96
23	0.15	0.5	0.5	7.36	0.33	11.10	0.43	7.79	0.33	7.79	0.33	12.20
24	0.15	0.5	0.7	7.39	0.34	11.19	0.44	8.29	0.32	8.29	0.33	3.82
25	0.15	0.75	0.3	9.71	0.36	13.21	0.48	8.30	0.37	8.30	0.37	33.07
26	0.15	0.75	0.5	7.67	0.33	11.24	0.44	8.49	0.33	8.49	0.33	8.81
27	0.15	0.75	0.7	7.98	0.35	11.88	0.45	8.21	0.33	8.21	0.33	4.24
28	0.15	1	0.3	10.41	0.38	14.14	0.51	8.74	0.38	8.74	0.38	31.87
29	0.15	1	0.5	9.32	0.35	12.60	0.48	9.09	0.35	9.09	0.35	6.74
30	0.15	1	0.7	9.47	0.36	12.54	0.48	8.73	0.34	8.73	0.35	5.64
31	0.2	0	0.3	36.14	0.47	61.10	0.67	40.44	0.75	41.95	0.75	57.53
32	0.2	0	0.5	15.10	0.36	26.95	0.49	16.03	0.38	16.46	0.39	37.74
33	0.2	0	0.7	9.18	0.33	12.76	0.45	8.44	0.33	8.44	0.34	18.55
34	0.2	0.25	0.3	17.90	0.42	31.73	0.58	9.42	0.45	10.33	0.45	48.42
35	0.2	0.25	0.5	8.28	0.34	11.17	0.45	8.14	0.34	8.14	0.34	21.03
36	0.2	0.25	0.7	8.82	0.34	12.04	0.45	8.34	0.33	8.34	0.33	5.56
37	0.2	0.5	0.3	10.07	0.38	13.57	0.53	8.93	0.40	8.93	0.40	42.47
38	0.2	0.5	0.5	8.13	0.34	10.80	0.45	8.07	0.33	8.07	0.33	14.36
39	0.2	0.5	0.7	7.55	0.32	10.75	0.45	8.10	0.33	8.10	0.33	3.94
40	0.2	0.75	0.3	10.34	0.41	13.86	0.54	9.29	0.40	9.29	0.40	39.24
41	0.2	0.75	0.5	8.91	0.36	12.30	0.48	8.49	0.34	8.49	0.34	11.47
42	0.2	0.75	0.7	8.87	0.34	11.80	0.47	8.68	0.34	8.68	0.34	5.25
43	0.2	1	0.3	12.83	0.42	16.43	0.57	9.65	0.43	9.65	0.42	38.86
44	0.2	1	0.5	11.17	0.39	14.89	0.51	9.44	0.37	9.44	0.37	10.20
45	0.2	1	0.7	10.86	0.38	13.94	0.51	9.56	0.38	9.56	0.38	8.07
46	0.25	0	0.3	42.89	0.58	57.09	0.85	30.52	1.04	29.77	1.04	62.64
47	0.25	0	0.5	15.39	0.37	28.11	0.51	19.25	0.40	19.75	0.40	41.47
48	0.25	0	0.7	9.63	0.33	13.20	0.45	7.87	0.33	7.87	0.33	21.39
49	0.25	0.25	0.3	27.64	0.50	39.61	0.68	13.57	0.52	13.28	0.51	53.83
50	0.25	0.25	0.5	8.48	0.34	11.44	0.45	8.95	0.34	8.95	0.34	24.11
51	0.25	0.25	0.7	8.09	0.33	10.92	0.45	8.40	0.33	8.40	0.33	5.94
52	0.25	0.5	0.3	11.90	0.41	17.40	0.56	8.33	0.43	8.33	0.43	47.81
53	0.25	0.5	0.5	8.27	0.35	11.93	0.46	8.48	0.34	8.48	0.34	16.85
54	0.25	0.5	0.7	8.65	0.32	12.29	0.45	8.14	0.33	8.14	0.33	4.35
55	0.25	0.75	0.3	12.40	0.43	15.98	0.59	8.93	0.45	8.93	0.45	46.04
56	0.25	0.75	0.5	11.01	0.38	14.71	0.50	9.43	0.37	9.43	0.37	15.40
57	0.25	0.75	0.7	10.23	0.37	13.30	0.50	8.87	0.37	8.87	0.37	7.46
58	0.25	1	0.3	15.66	0.48	19.55	0.66	11.61	0.51	11.61	0.50	46.34
59	0.25	1	0.5	13.41	0.44	17.91	0.59	10.78	0.43	10.78	0.44	15.23
61	0.3	0	0.3	12.48	0.44	16.68	0.59	11.39	0.43	11.39	0.43	11.68
62	0.3	0	0.5	17.82	0.39	32.14	0.52	21.68	0.43	22.27	0.43	44.84
63	0.3	0	0.7	9.62	0.34	14.63	0.45	8.81	0.34	8.81	0.34	24.15
64	0.3	0.25	0.3	36.28	0.59	47.12	0.78	21.57	0.62	20.50	0.61	58.89
65	0.3	0.25	0.5	9.03	0.34	12.06	0.45	8.15	0.34	8.15	0.34	27.17
66	0.3	0.25	0.7	7.86	0.33	11.49	0.44	7.99	0.33	7.99	0.33	6.52
67	0.3	0.5	0.3	67.82	0.56	95.03	0.81	14.72	0.50	14.79	0.50	54.09
68	0.3	0.5	0.5	8.97	0.37	12.31	0.49	8.48	0.35	8.48	0.36	20.37
69	0.3	0.5	0.7	9.75	0.36	12.67	0.47	8.59	0.35	8.59	0.35	5.60
70	0.3	0.75	0.3	14.53	0.53	18.81	0.71	10.70	0.55	10.70	0.54	53.76
71	0.3	0.75	0.5	12.97	0.42	17.21	0.57	10.65	0.41	10.65	0.42	20.54
72	0.3	0.75	0.7	12.49	0.43	16.64	0.58	11.07	0.42	11.07	0.42	10.87
73	0.3	1	0.3	31.64	0.65	44.34	0.91	14.61	0.72	17.63	0.72	55.70
74	0.3	1	0.5	25.72	0.55	43.72	0.76	14.75	0.59	18.58	0.60	22.90
76	0.5	0	0.3	24.00	0.57	38.25	0.76	15.35	0.59	17.12	0.59	17.65
77	0.5	0	0.5	91.57	0.51	155.33	0.72	34.39	0.76	37.13	0.76	57.30
79	0.5	0.25	0.3	12.89	0.35	19.13	0.48	10.11	0.37	10.16	0.37	34.94
90	0.5	1	0.7	10.36	0.36	14.41	0.50	9.55	0.37	9.55	0.37	12.88

Selected TopOpt for Benchmark



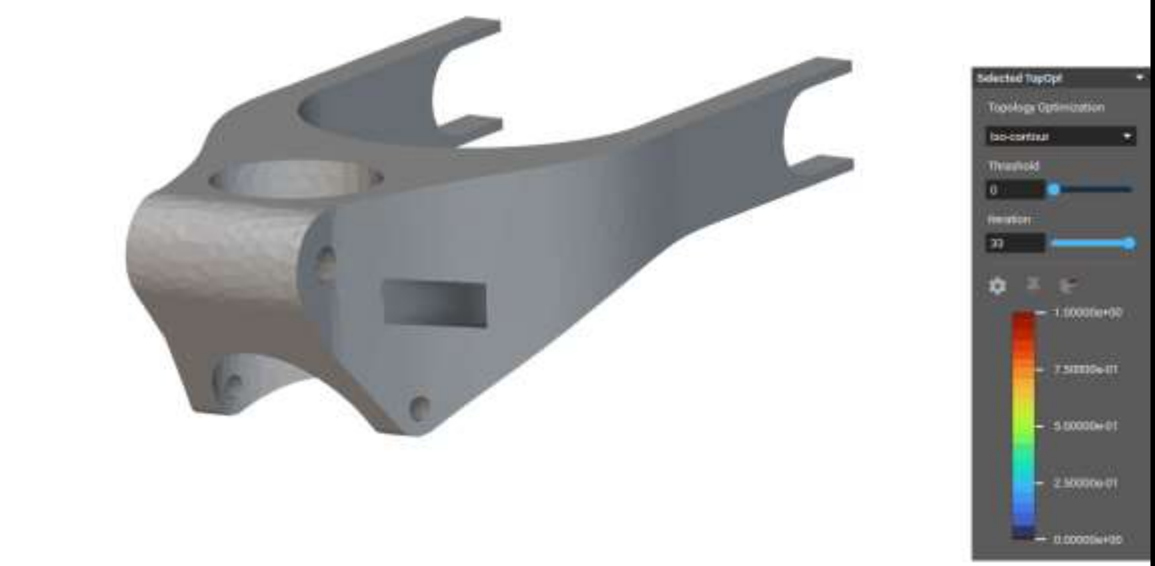
5 Topology Optimizations with the highest weight savings

Iteration Number	Threshold Value	Boundary Penalty	Volume Fraction	LC1 Max Stress (MPa)	LC1 Max Displ (mm)	LC2 Max Stress (MPa)	LC2 Max Displ (mm)	LC3 Max Stress (MPa)	LC3 Max Displ (mm)	LC4 Max Stress (MPa)	LC4 Max Displ (mm)	Weight Savings(%)
31	0.2	0	0.3	36.14	0.47	61.10	0.67	40.44	0.75	41.95	0.75	57.53
46	0.25	0	0.3	42.89	0.58	57.09	0.85	30.52	1.04	29.77	1.04	62.64
64	0.3	0.25	0.3	36.28	0.59	47.12	0.78	21.57	0.62	20.50	0.61	58.89
73	0.3	1	0.3	31.64	0.65	44.34	0.91	14.61	0.72	17.63	0.72	55.70
77	0.5	0	0.5	91.57	0.51	155.33	0.72	34.39	0.76	37.13	0.76	57.30

Reminder: Top Opt Limitations in weight saving capabilities

Any more aggressive topology optimizations (low VF, high Threshold, etc.) had disconnected components and led to "Error" (i.e. not a valid design)

→ Limitation of Topology Optimization to further reduce weight



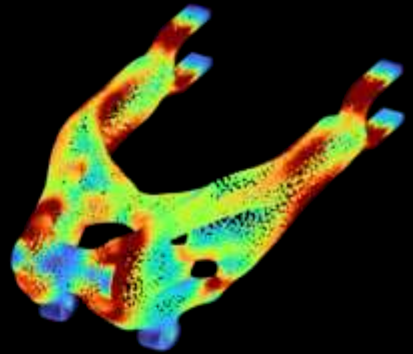
Iteration Number	Threshold Value	Boundary Penalty	Volume Fraction	LC1 Max Stress (MPa)	LC1 Max Displ (mm)	LC2 Max Stress (MPa)	LC2 Max Displ (mm)	LC3 Max Stress (MPa)	LC3 Max Displ (mm)	LC4 Max Stress (MPa)	LC4 Max Displ (mm)	Weight Savings(%)	Error?
60	0.25	1	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
75	0.3	1	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
78	0.5	0	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
80	0.5	0.25	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
81	0.5	0.25	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
82	0.5	0.5	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
83	0.5	0.5	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
84	0.5	0.5	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
85	0.5	0.75	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
86	0.5	0.75	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
87	0.5	0.75	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
88	0.5	1	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error
89	0.5	1	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Error

TopOpt + Field-Driven Design

Fair comparison approach: Make TopOpt + Field-Driven Designs around the **same weight savings** as the Best TopOpt (around 60%) so that **structural performance comparison** is fair!

BEST TopOpt (VF=0.3,BP=0,Th=0.2)

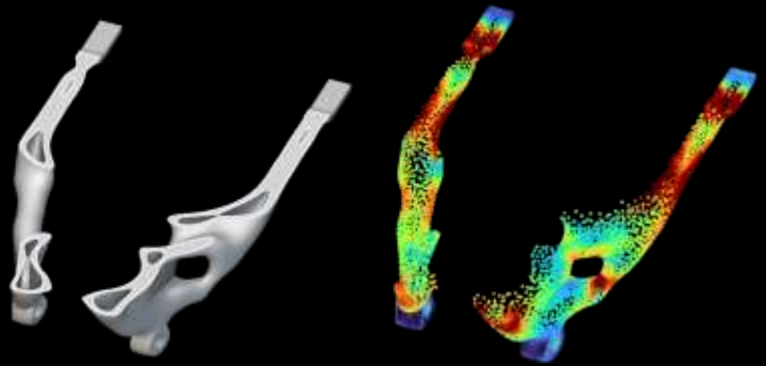
Weight Savings = 57%



TopOpt (VF=0.3,BP=0.5,Th=0.25) + Thickness re-adjustment (TR)

Up to 4mm thickness removal in low stress areas

Weight Savings (TopOpt only) = 48%
Weight Savings (TopOpt + TR) = 59%



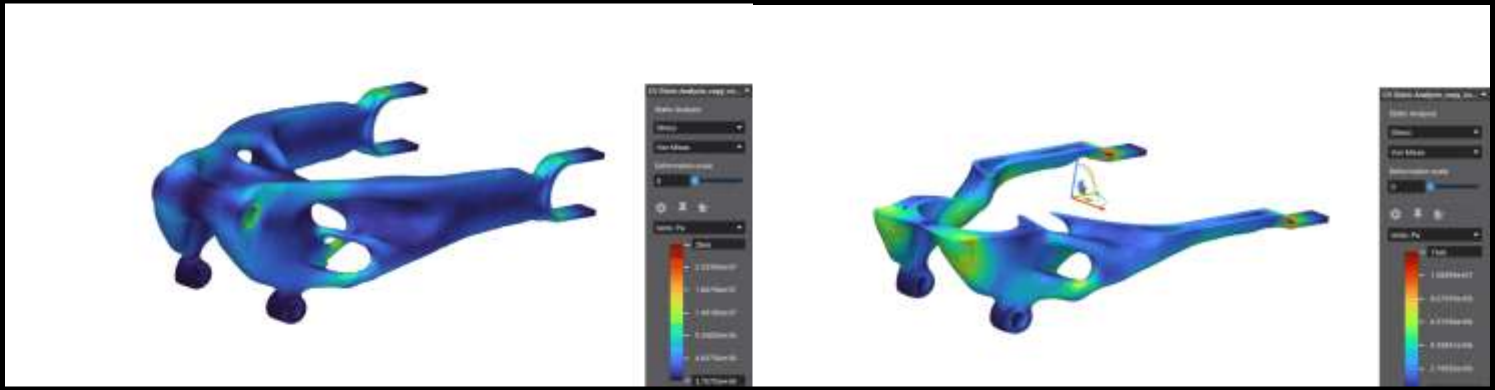
TopOpt (VF=0.3,BP=0.5,Th=0.25) + Variable Shelling (VS)

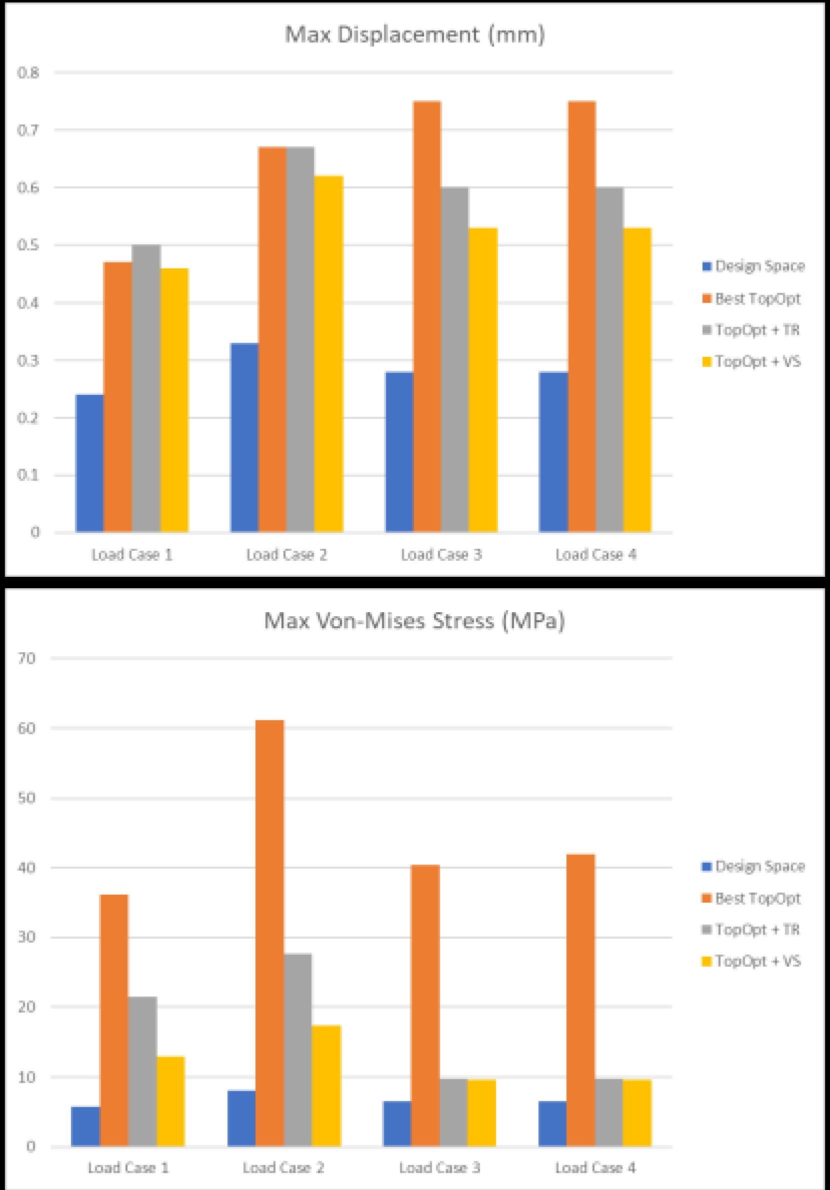
Low stress areas: 3mm thickness
High stress areas: 10mm thickness or solid

Weight Savings (TopOpt only) = 48%
Weight Savings (TopOpt + VS) = 58%

Structural Performance Summary

- For all load cases, TopOpt + Variable Shelling provides the lowest displacement and stress values
- Both Field-driven options provide superior performance for displacement and stress
- The field-driven designs had been tweaked to match the same weight savings as the best Top Opt (~60%), but based on the structural performance, more aggressive weight savings are possible with these techniques





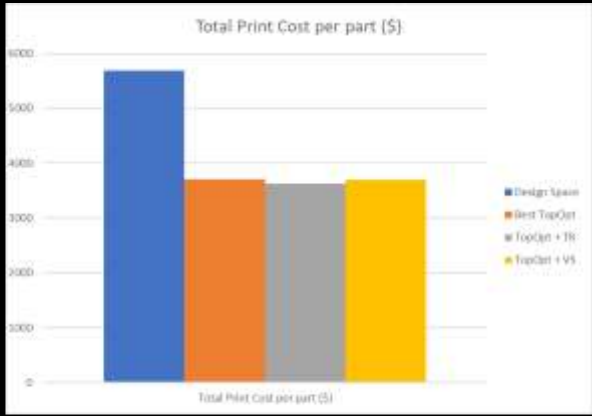
Manufacturability Assesment

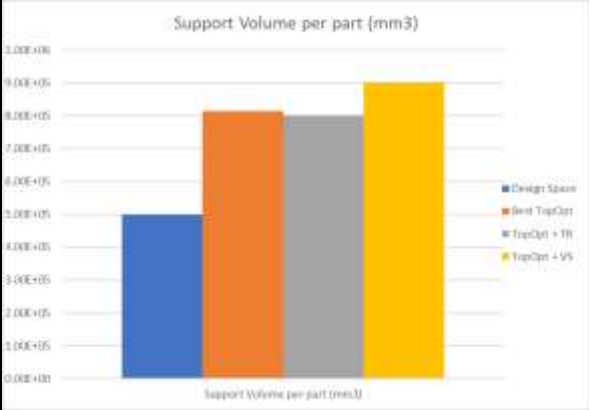
Strategy example :

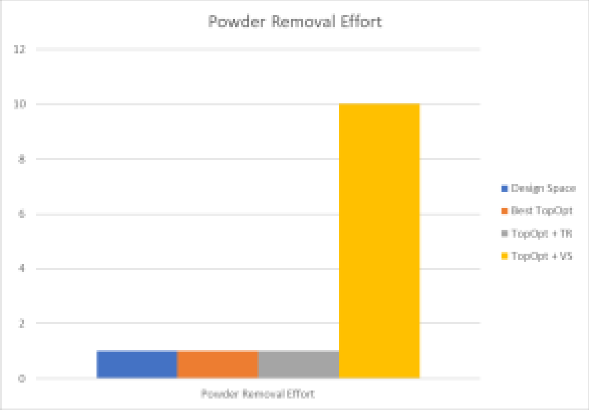
Minimize print cost and time by minimizing part height

- Up to 30% print time saving (vs design space)
- Up to 50% cost reduction

Minimize part post-processing cost by minimizing support volume







Print assumptions for estimation (LPBF Process)

Offset from build pla...	10	mm
Overhang angle:	45	deg
Feature size for Over...	3	mm
Supports Unit cell ty...	Body centered cubic	
Supports Unit cell si...	20 20 20	mm
Supports Thickness:	3	mm
Rotate Angle (rad):	0	
Layer height (mm):	0.06	mm
Contour Spd (mm/s):	800	$mm\ s^{-1}$
Contour Offset (mm):	0.25	mm
Hatch Spd (mm/s):	1200	$mm\ s^{-1}$
Hatch Spacing (mm):	0.35	mm
Hatch Angle (rad):	1.16937	
Coater Delay (s):	10	s
Cost /hr ($):	150	
Mat'l Cost ($/kg):	350	
Mat'l Density (g/cc):	2.59	
Build Plate length (m...	600	mm
Build Plate width (m...	600	mm

nTopology

Performance & Manufacturability Summary

- **Automated design** generation using **nTopCL** (90 designs in ≈8 hours overnight)

- The **Variable Shell** design shows the **best structural performance.** However, it faces the biggest **manufacturing challenges**
  1. Internal voids make powder removal challenging.
     “Escape holes” are needed. Integrated in the design or drilled after the print
  2. Internal voids aren’t self-supporting structures. This can be addressed in two ways:
     By adding lattice structures
     By generating shells that are self-supporting

- Lightweighting the part highly reduces additive mfg. time and cost (about 50%)

- Print time and cost, as well as support volume was similar for all optimized designs in this case

nTopology offers solutions to these challenges, making Variable Shell design feasible, to allow engineers to design these high performance, lightweight components

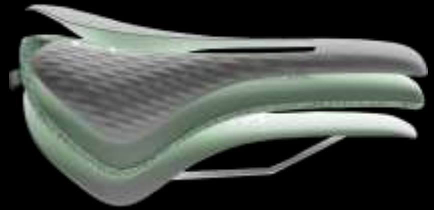
nTopology is unmatched in solving these design challenges

Lightweighting

Thermal Management

Mass Customization

Industrial Design



Architected Materials

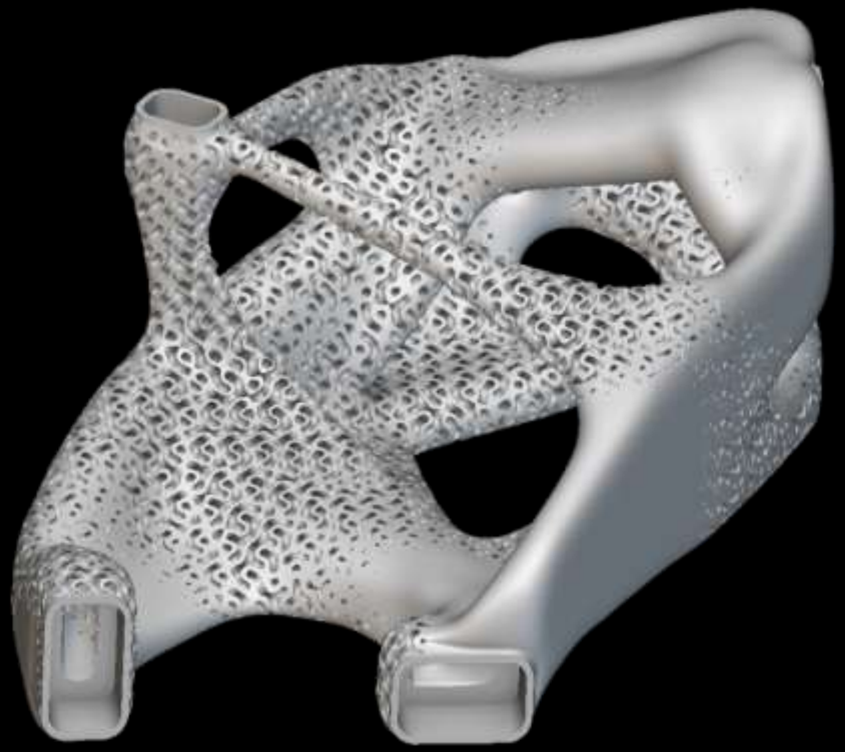
Manufacturing & Tooling

Thank you

Guenael Morvan

Application Engineer

guenaelmorvan@ntopology.com



Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

Reducing Support Structures & Distortion using Genesis Hatching

Outline

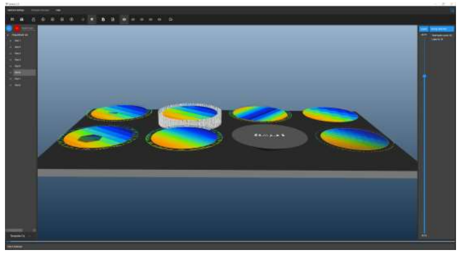
- Introduction
  - AMSIS GmbH
  - Genesis Hatching
- Simulationbased Hatching
- Advantages of Simulationbased Hatching for
  - Reducing distortion
  - Reducing supports
  - Material Properties
- Current Developments
- Summary

AMSIS GmbH: General information

Foundation: *June 2017 in Bremen, Germany*

Founder: *Prof. Dr. Vasily Ploshikhin*
Head of Airbus endowed chair ISEMP (University of Bremen)

Employees: *12 employees (June 2022)*



Product: **Simulation-based 3D-Printing software GENESIS**

Investors: *BAB ERDF participation fund*
HZG Additive Manufacturing Tech Fund

European Union
Investing in Bremen's Future
European Regional
Development Fund

FUNDED BY EFRE

HZGGROUP

GENESIS 3D-Printing Software

- Multi-Part/Support Import
- Multi-Part Placement
- Support Generation
- Slicing
- Simulation-based Hatching
- Layer adjusted Hatching
- Generation of Artificial Defects
- Build-job Export
- Template Management
- Project Saving

GENESIS 3.0

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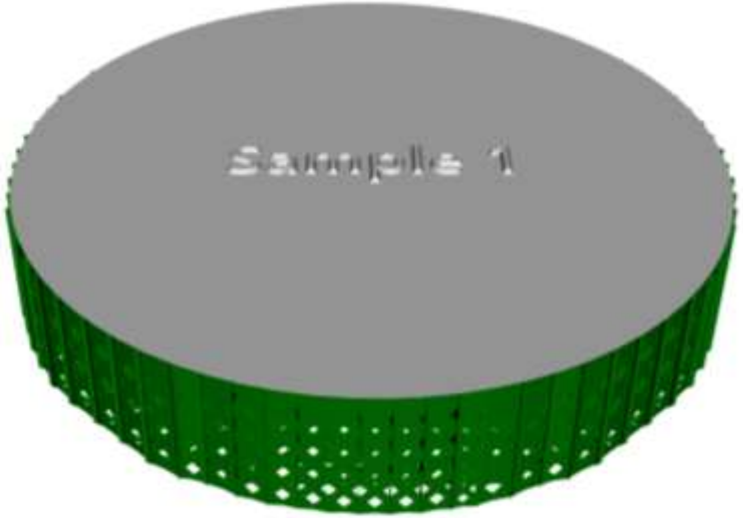
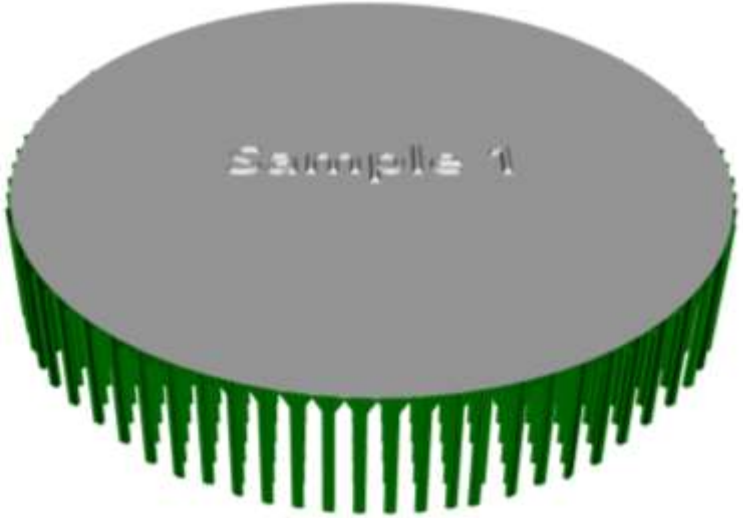
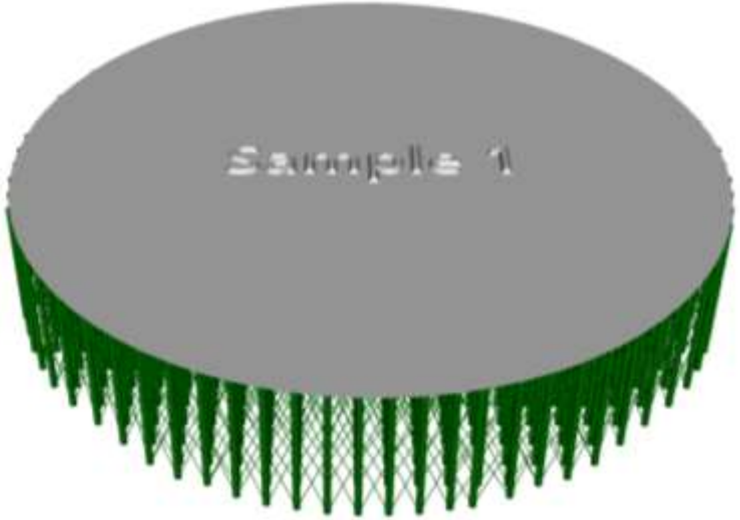
Automated support generation



Block Supports

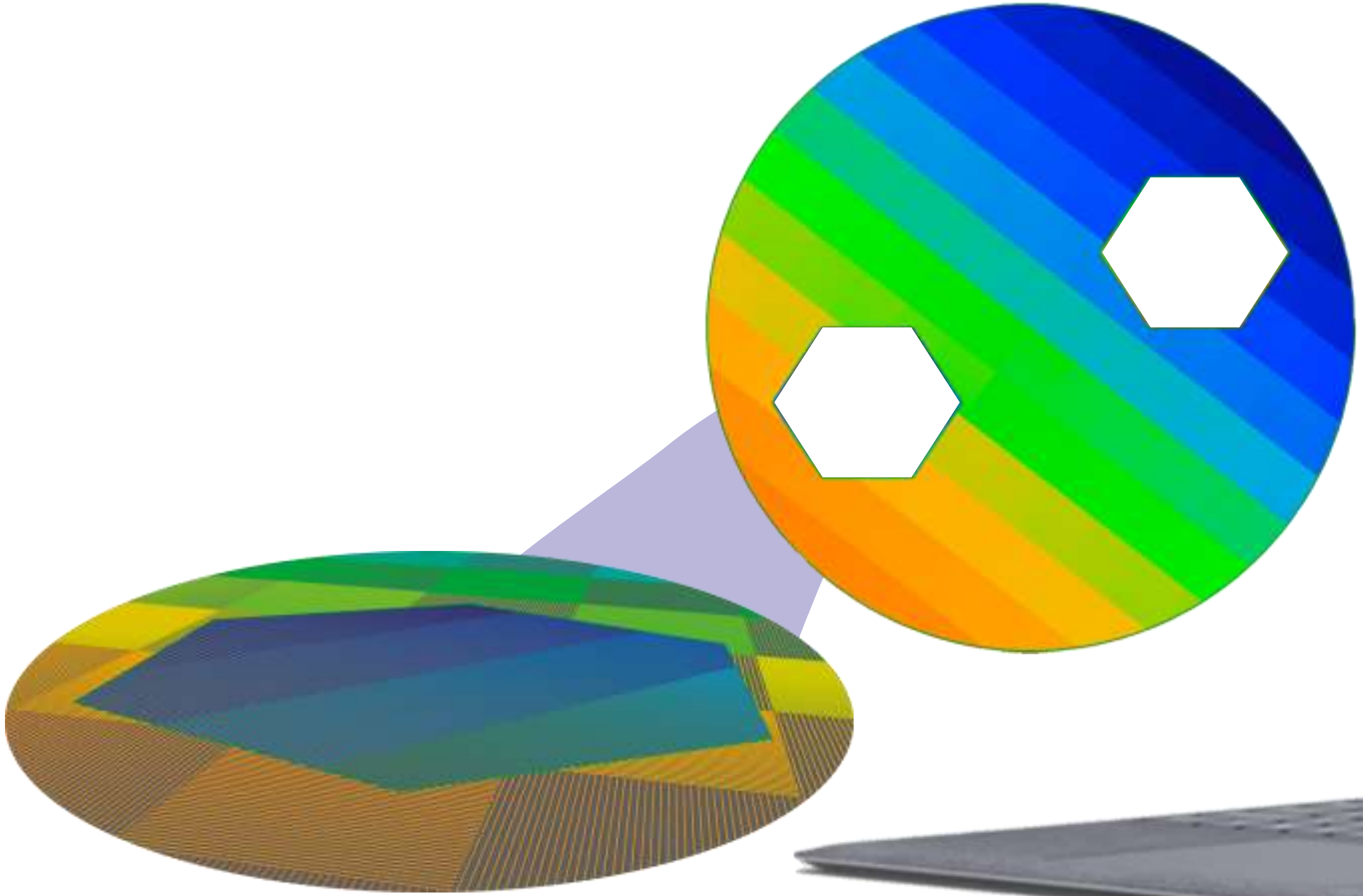


Arc Supports

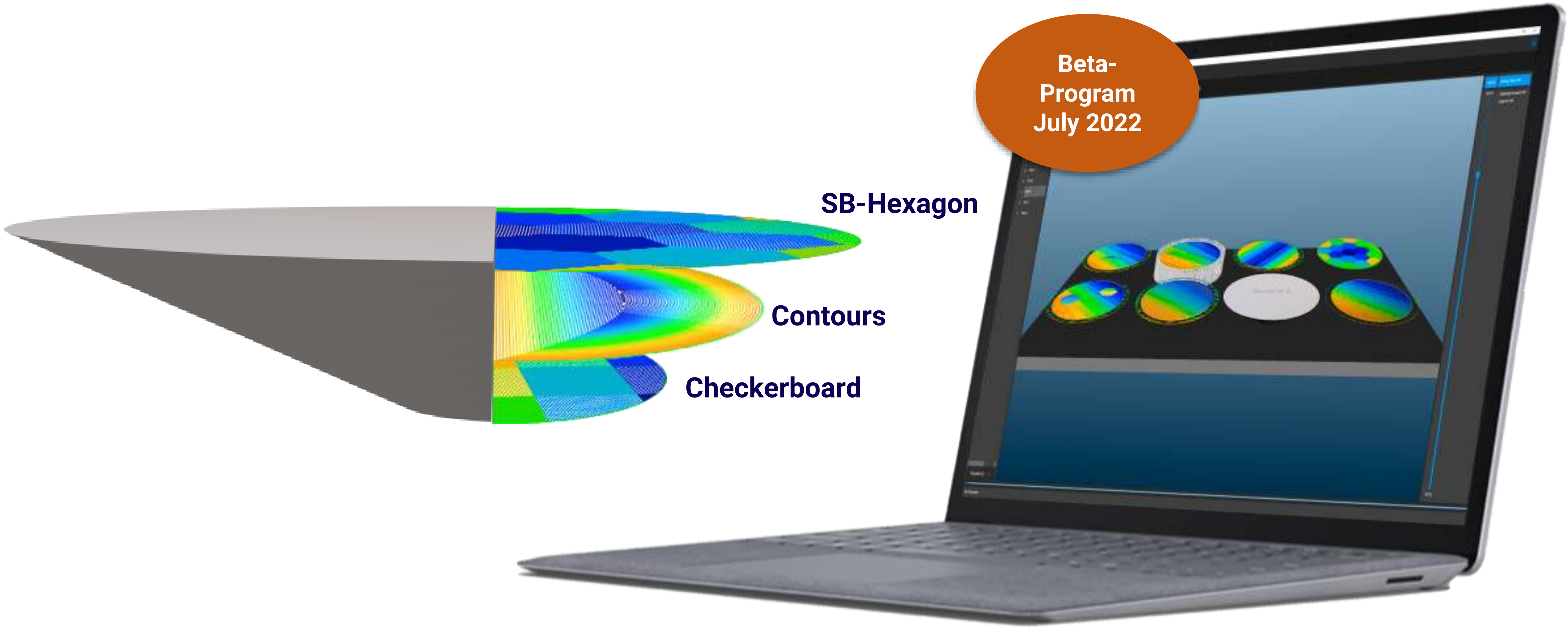


Cone Supports

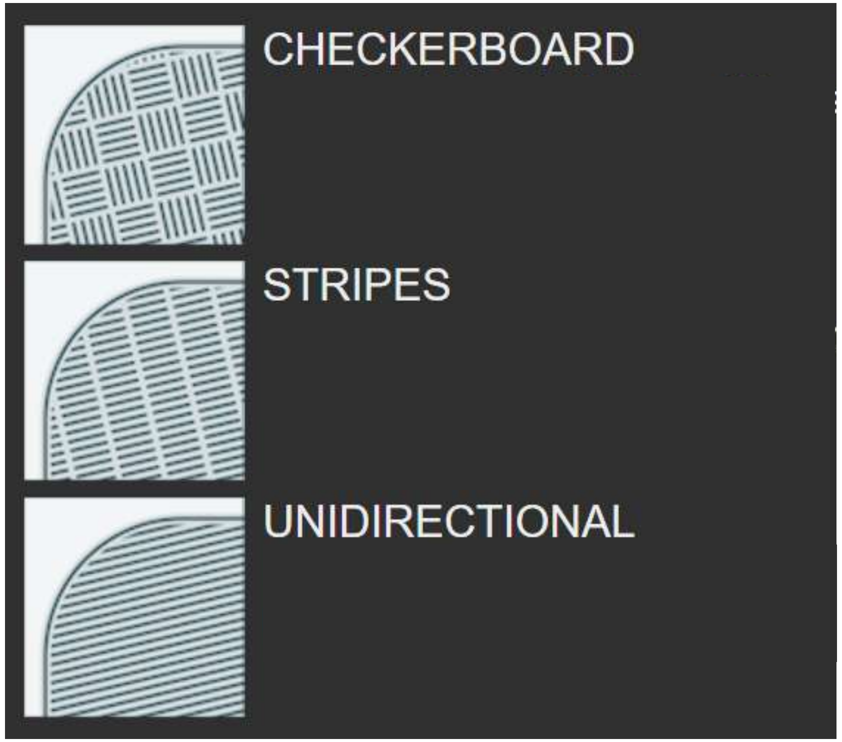
Multi Hatching / Defects withing one layer

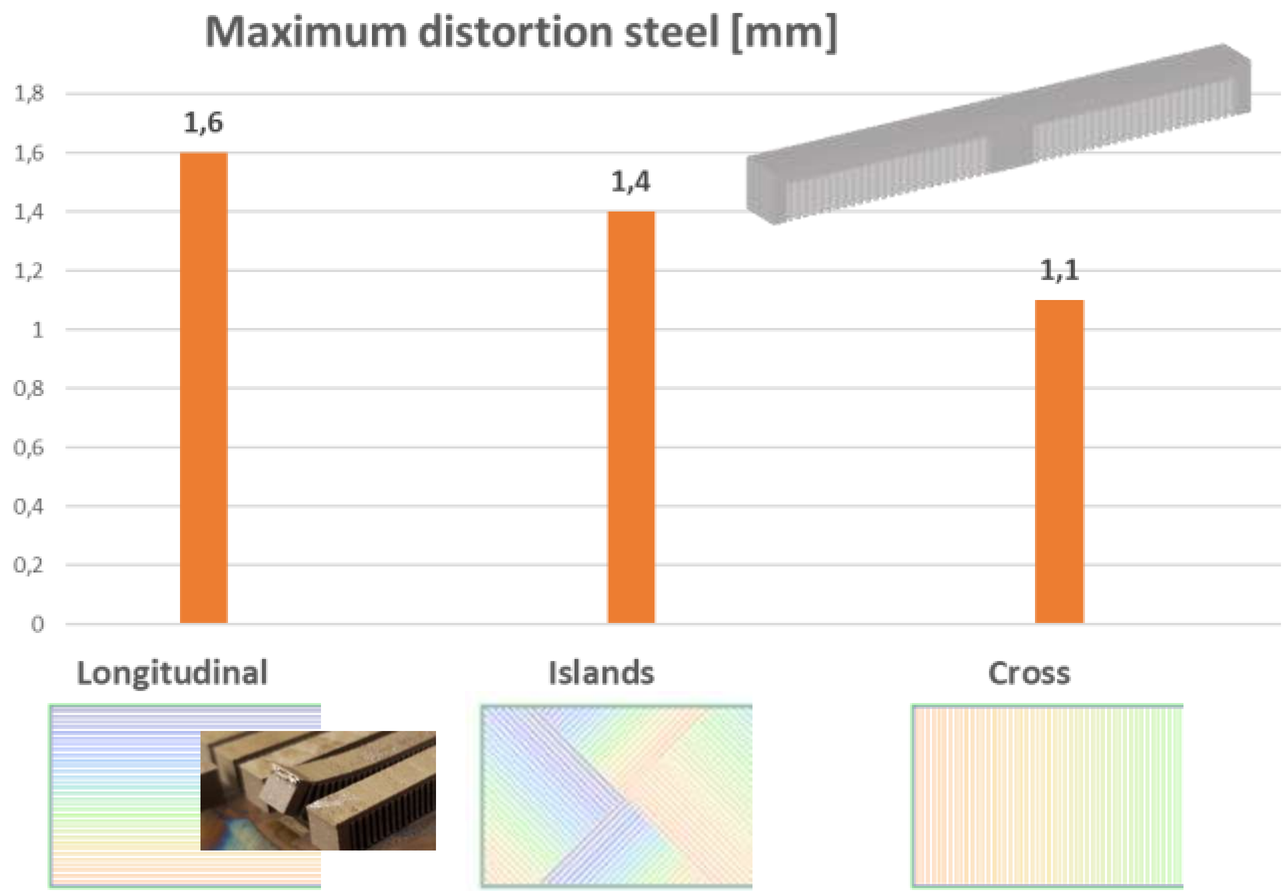


Layer Adjusted Hatching



Conventional hatching strategies Less Distortion (316L)





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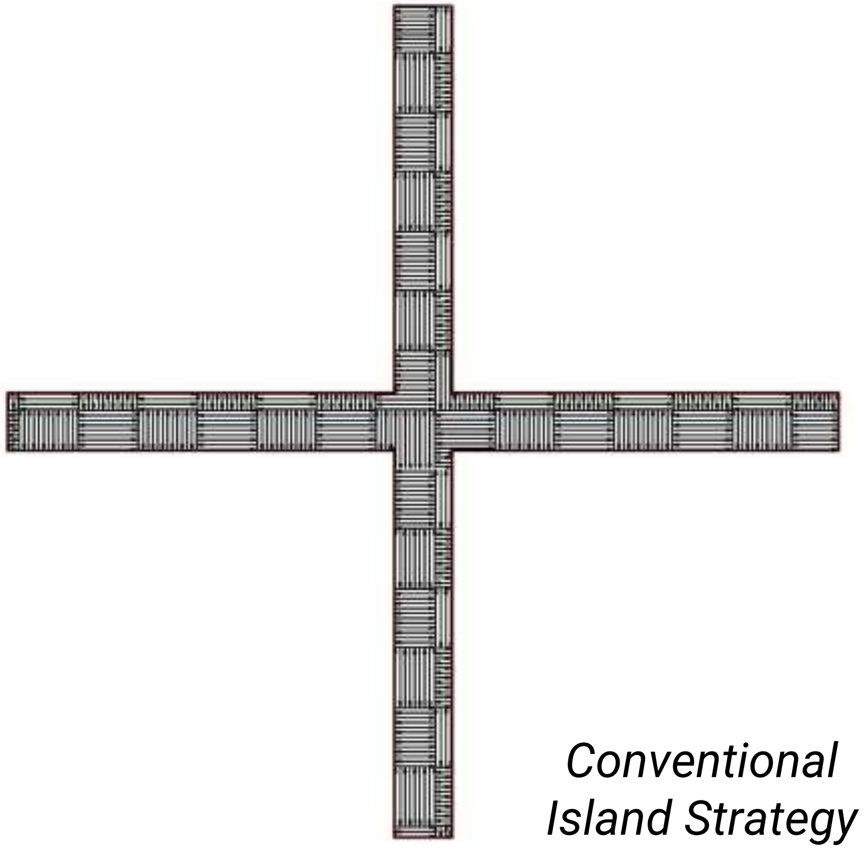
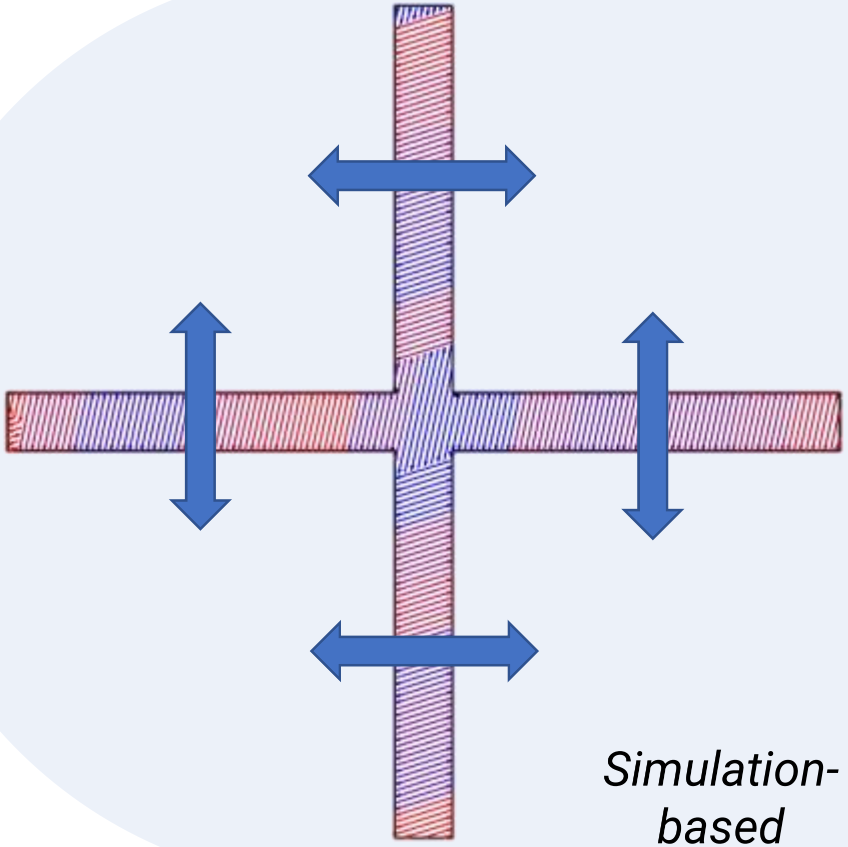
New less-distortion hatching

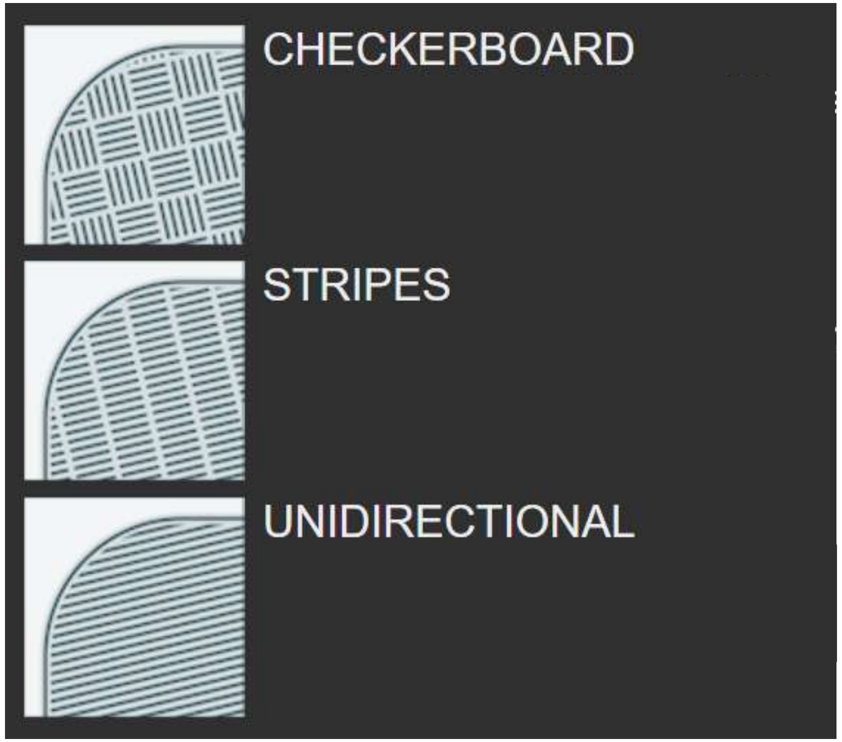


Conventional
Island Strategy

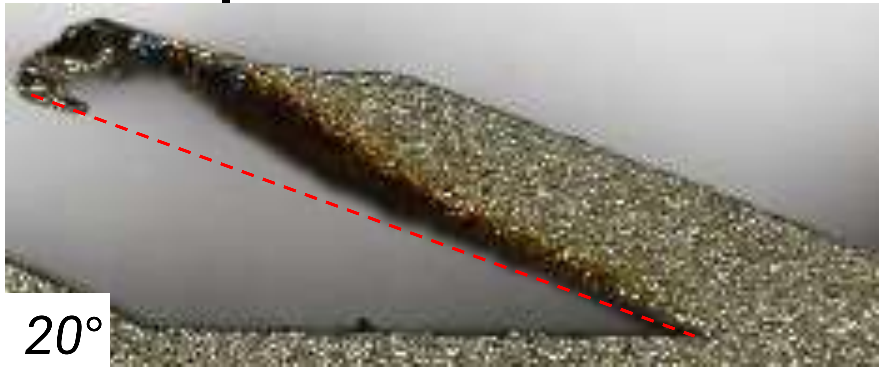


Simulation-
based
New Strategy

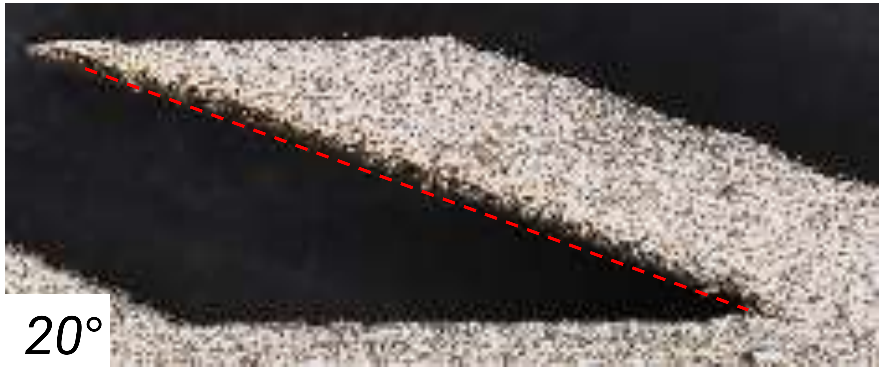
Conventional hatching strategies Less Supports (Ti64)



No Adaption



Adaption of sequence & orientation



(Illies 2020), ttps://media.suub.uni-bremen.de/handle/elib/4240

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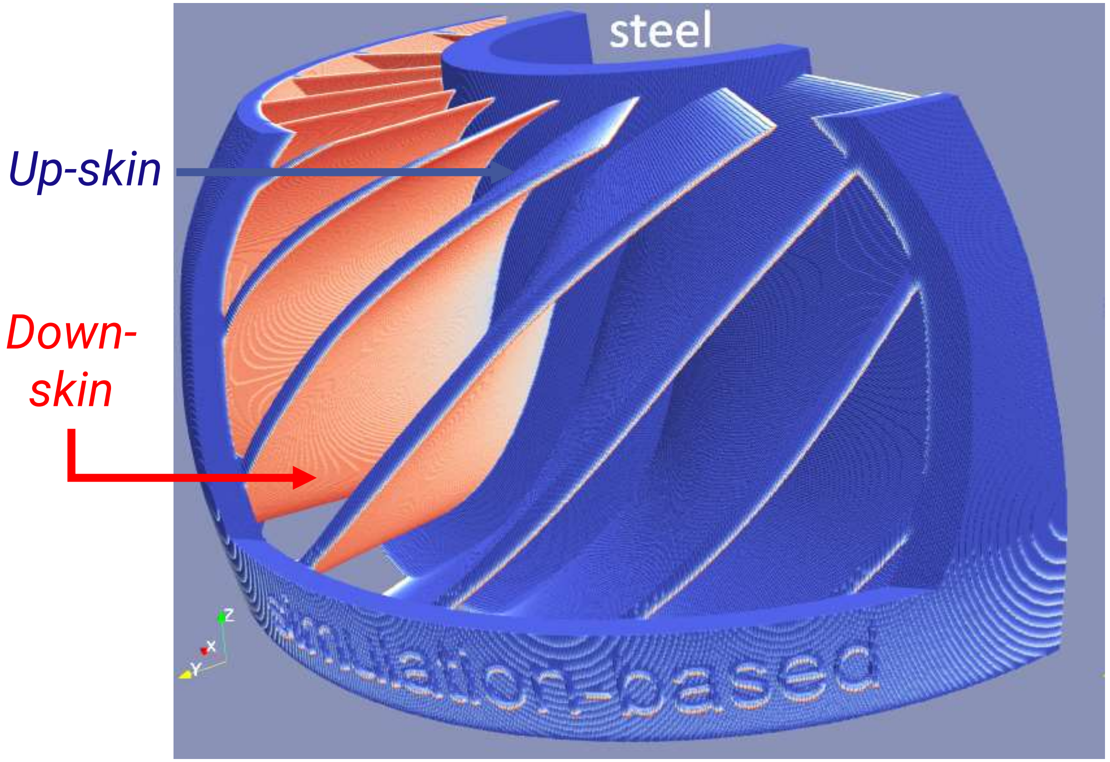
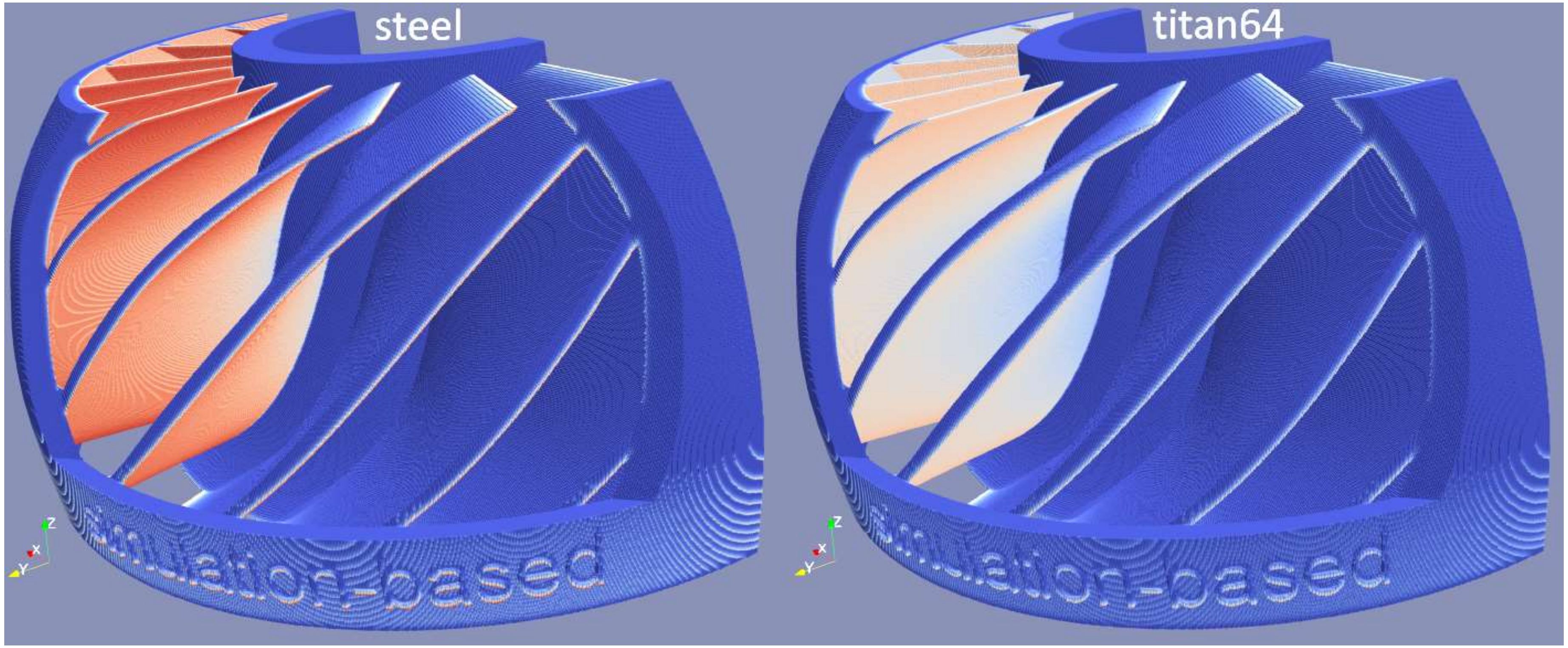
Simulation-based Segmentation & Hatching



SB-Segmentation:
automatic *material specific up & downskin detection*

State of the art = manual determination of these areas

Simulation-based Segmentation & Hatching



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Simulation-based Segmentation & Hatching

SB-Segmentation:
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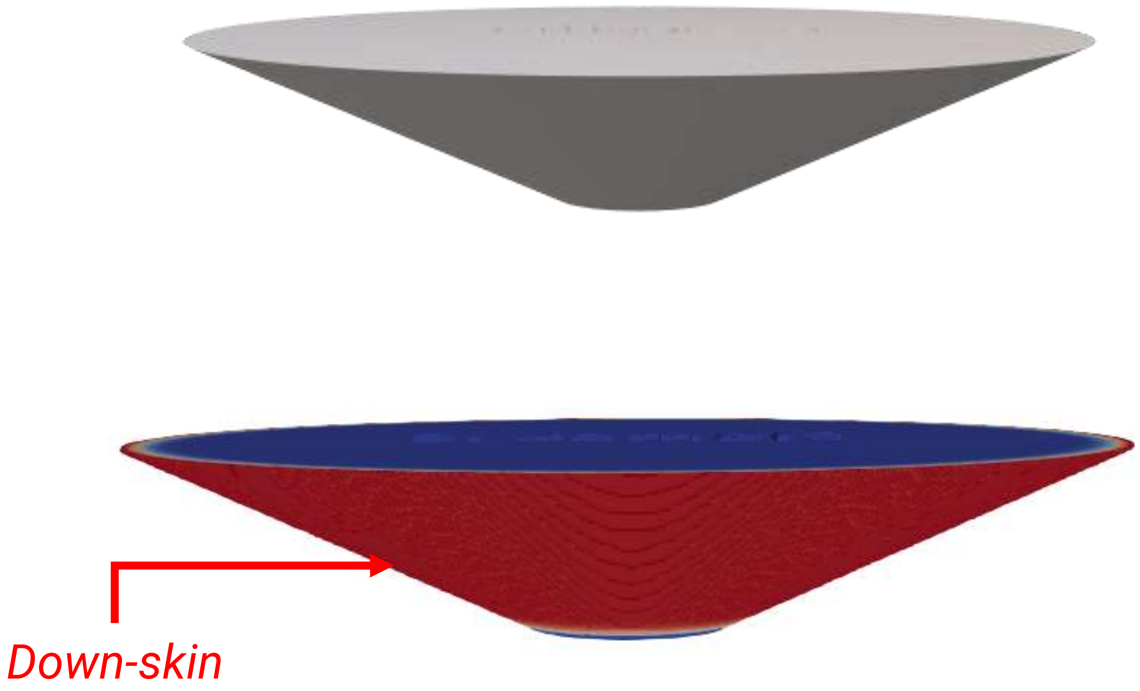
Simulation-based Segmentation & Hatching



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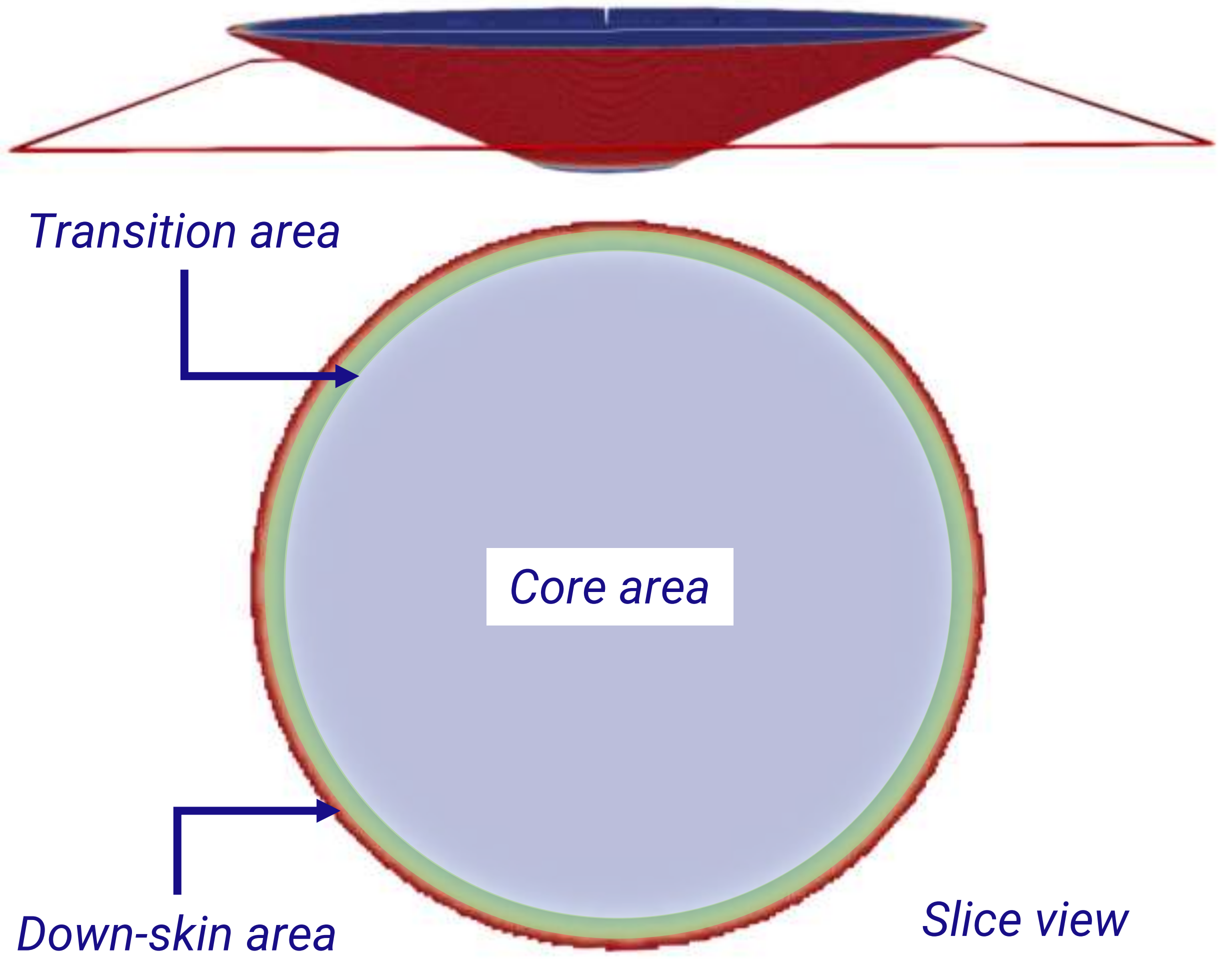
Simulation-based Segmentation & Hatching

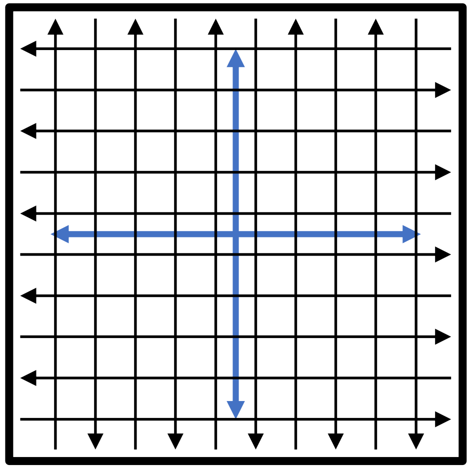


SB-Segmentation:
automatic *material specific up & downskin detection*

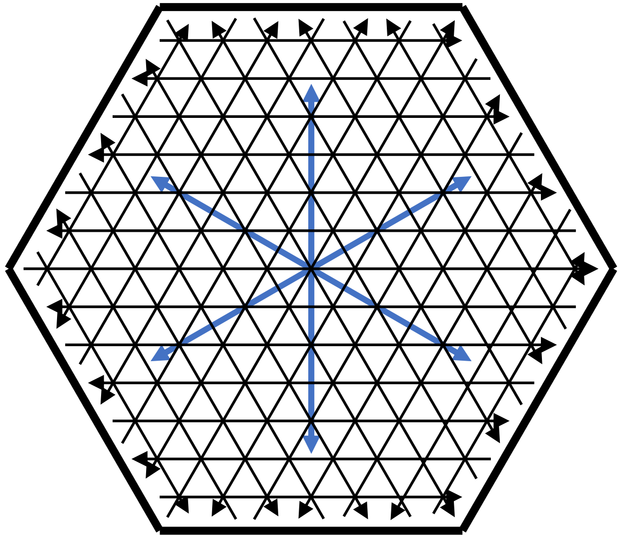
State of the art = manual determination of these areas

Hatching Patterns for simulationbased strategies

Checkerboard
3 Possible Orientations

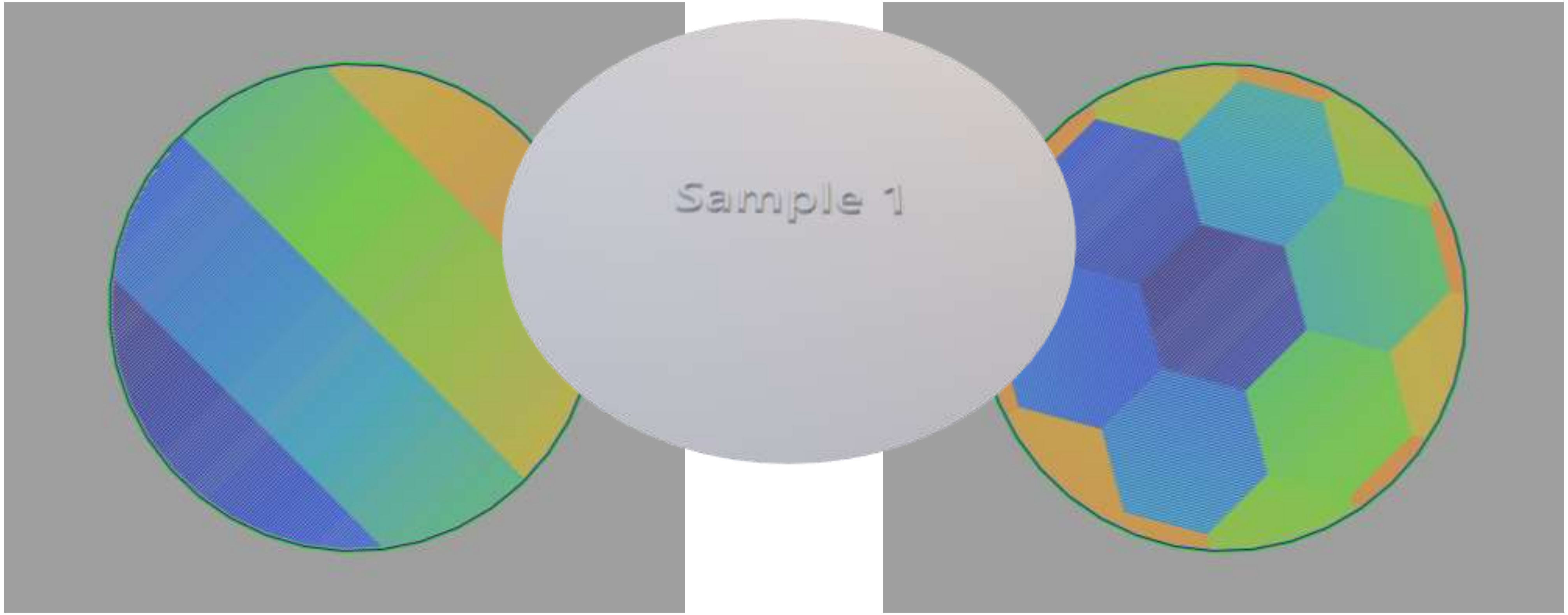


Hexagons
3 Possible Orientations



Conventional vs simulationbased Hatching (less supports)

Standard Stripes | *SB – Hexagon*



AMSIS
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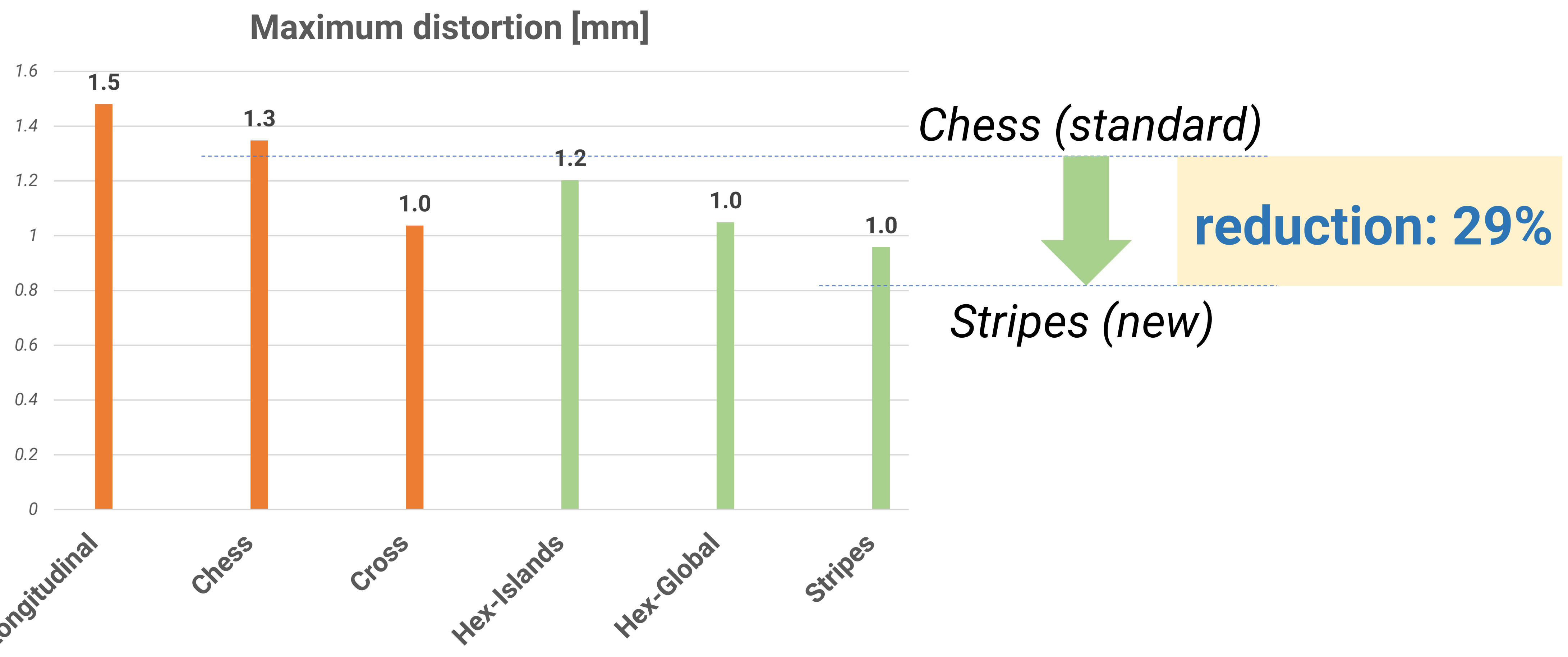
Steel 1.4404: up to 29% less distortion



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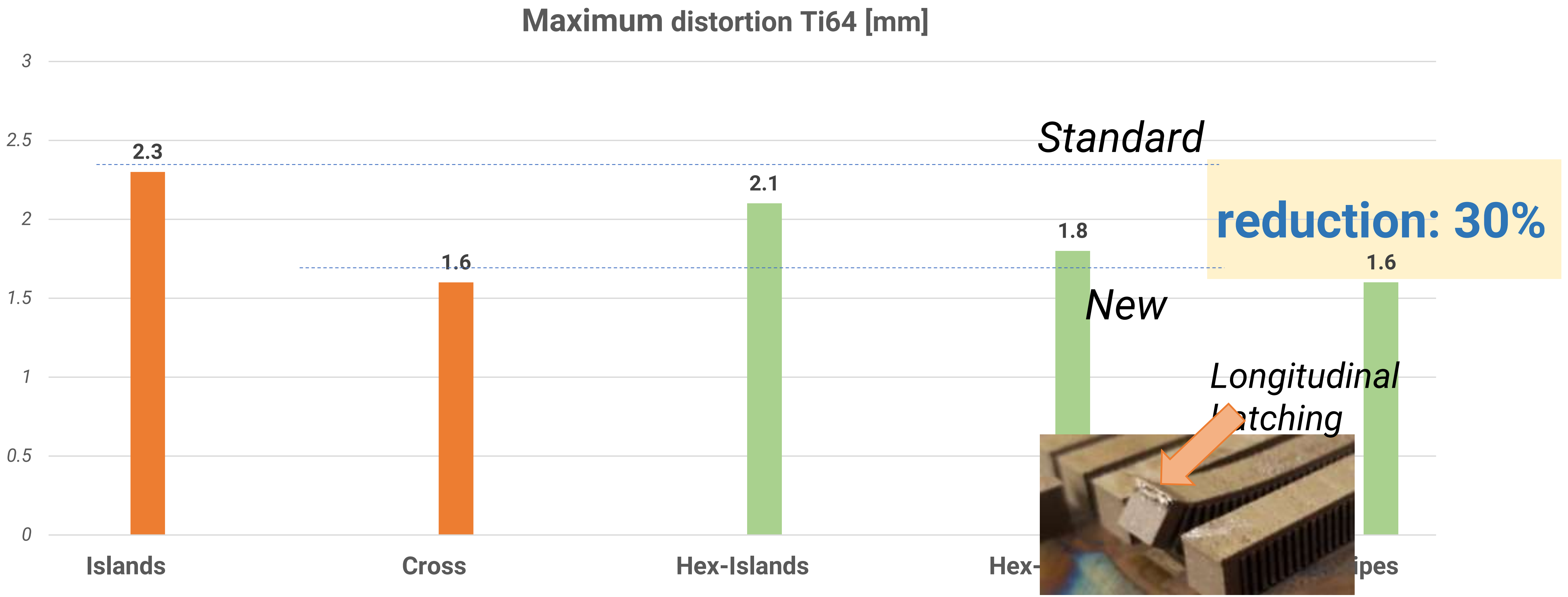
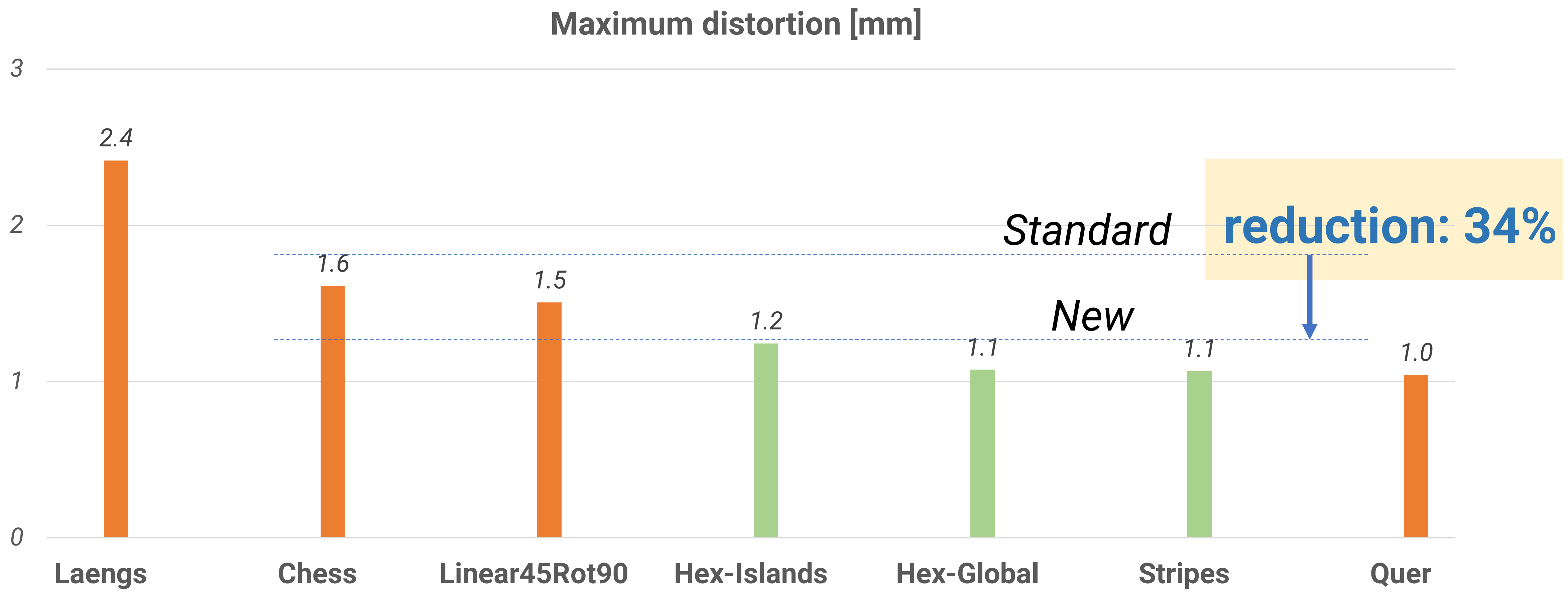
Titanium alloy Ti64: up to 30% less distortion



AlSi10Mg: 34% less distortion



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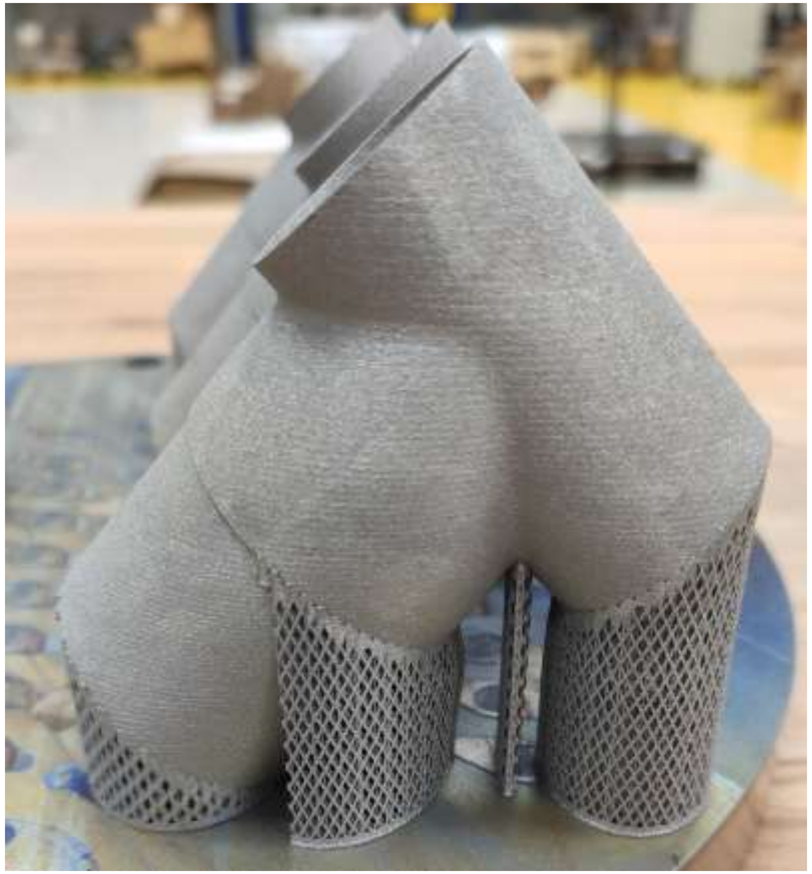
Demonstration Part

Conventional

simulationbased



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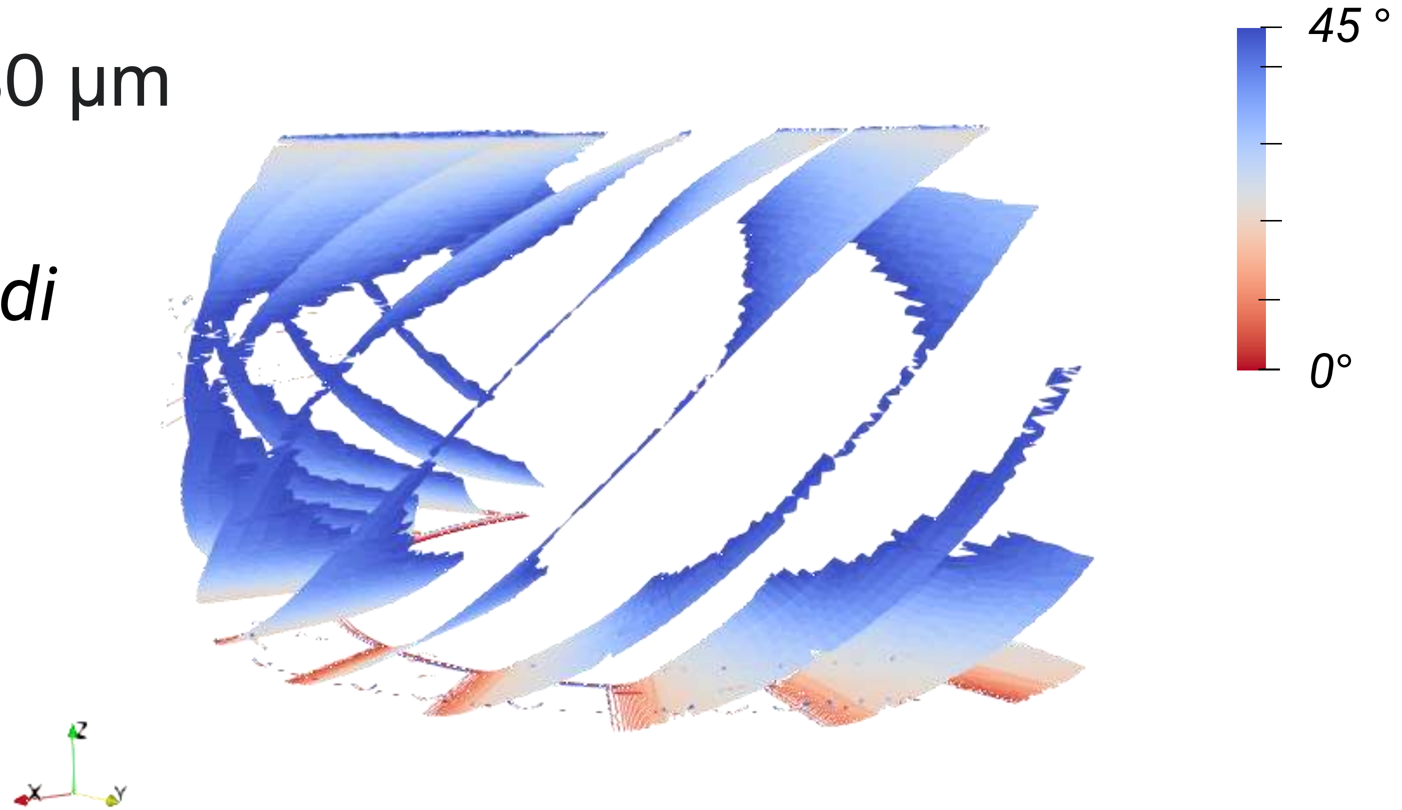
Support-free Demonstrator Parts

Support-free Demonstrator Parts

- Ti64/316l
- Layer height 60 µm/ 30 µm
- Minimum angle 23°
- SLM 500 / Aconity Midi



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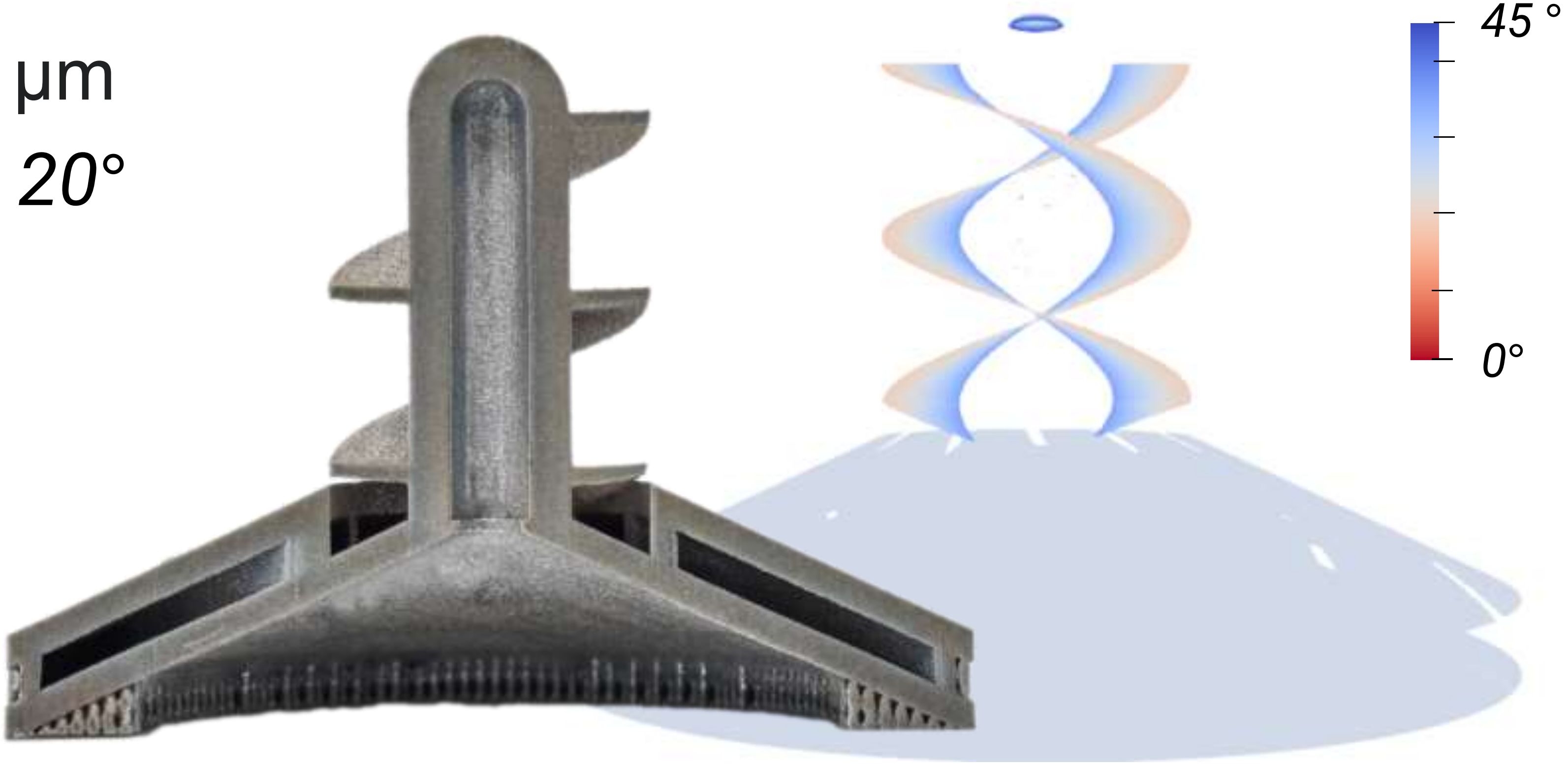
Support-free Demonstrator Parts

- Ti64
- Layer height 30 µm
- Minimum angle 20°
- SLM 500



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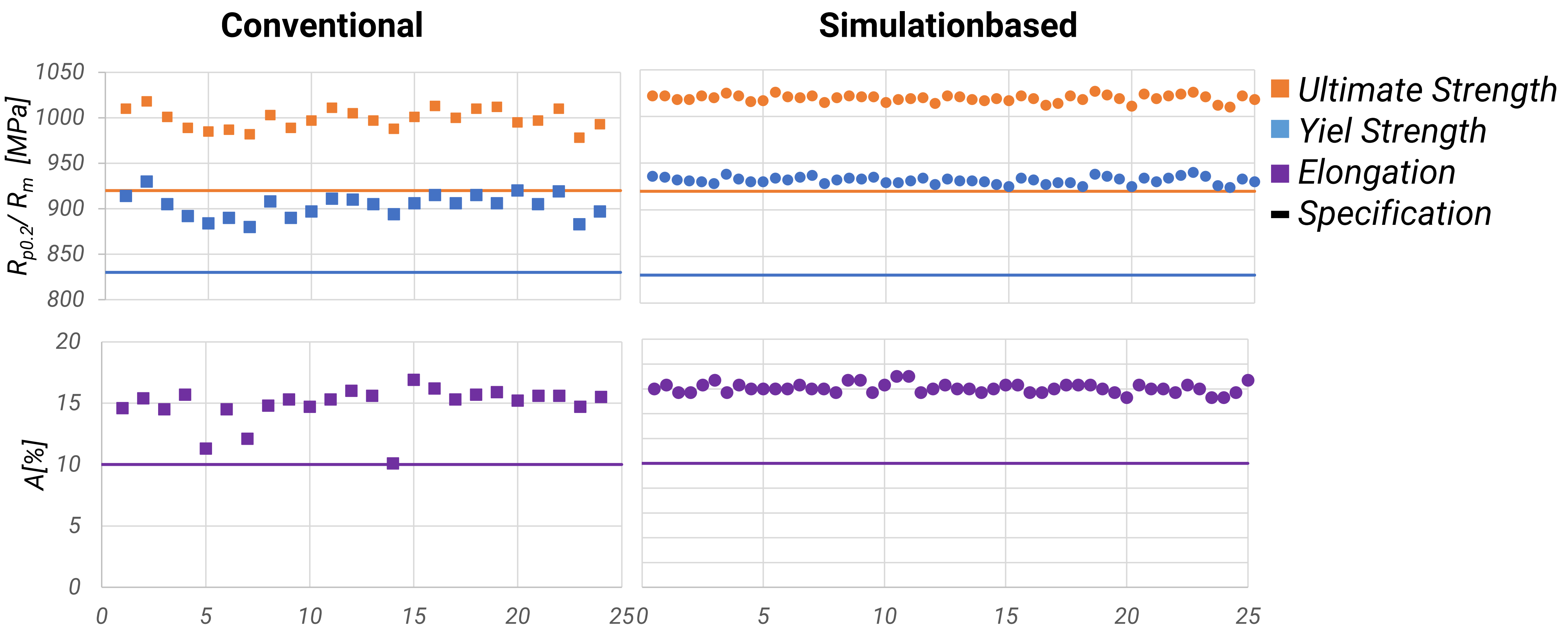
Mechanical Properties Ti64

- Tensile Specimen
- Printed in different angels and orientations
- Simulationbased less Supports Stragies have been used

Mechanical Properties Ti64



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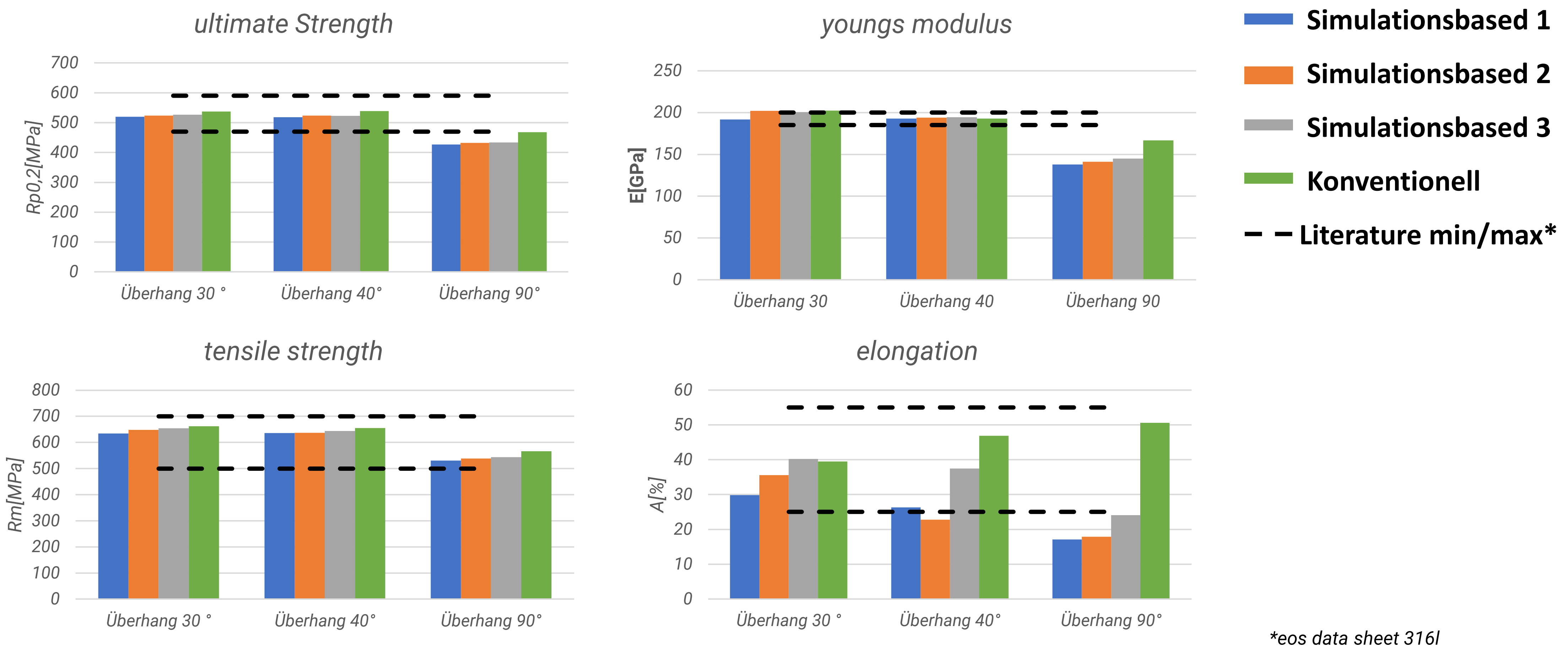
Mechanical Properties Steel 316L



*eos data sheet 316l

AMSIS ADDITIVE MANUFACTURING SOFTWARE FOR INDUSTRIAL SYSTEMS

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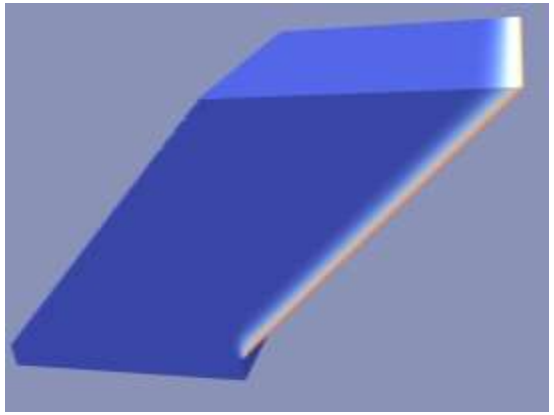
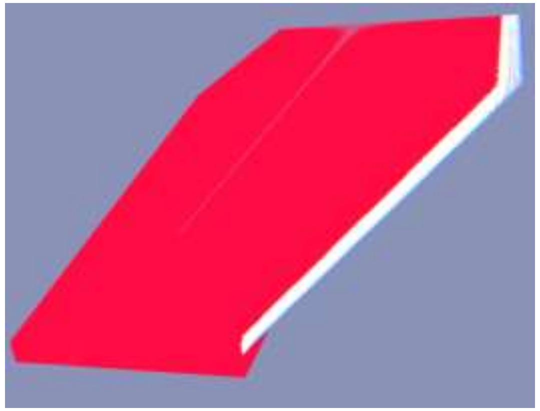
Development: Parameter Adaption Modul

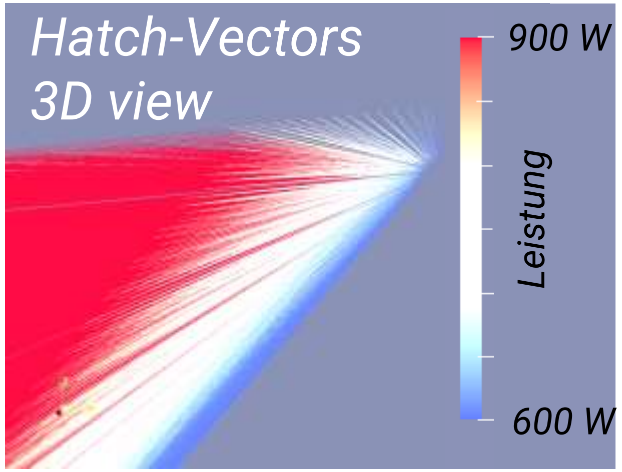
USPs: **automatic** *and* **materialspecific graded adaption** *of process parameters in specific component segments.*



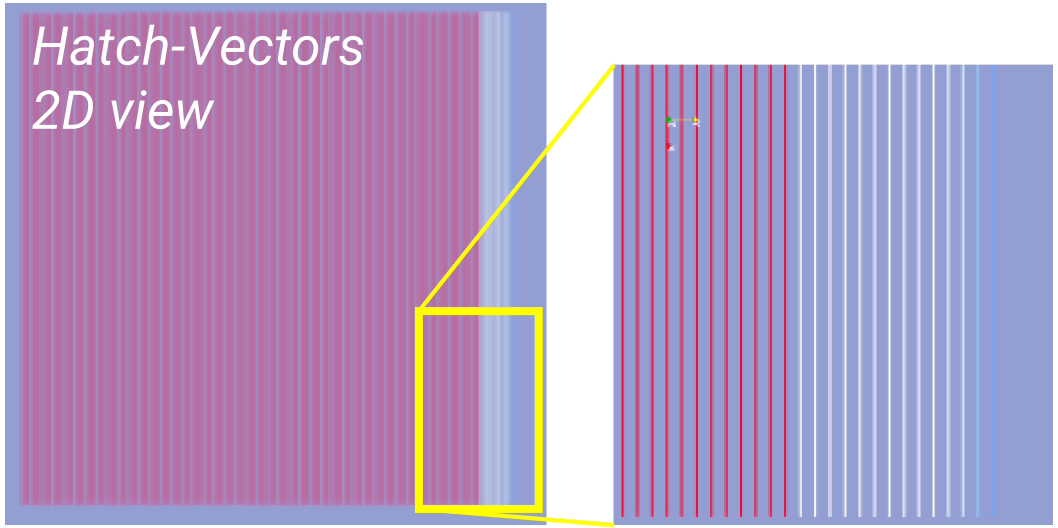
Thermal Segmentation



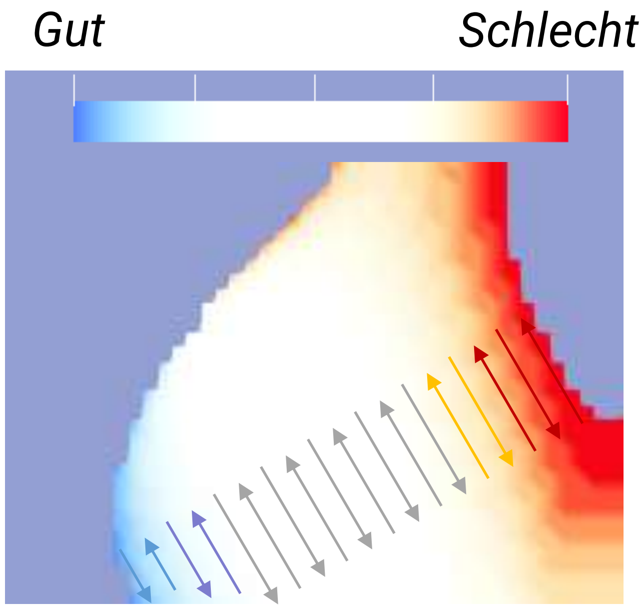
Parameter Adaption



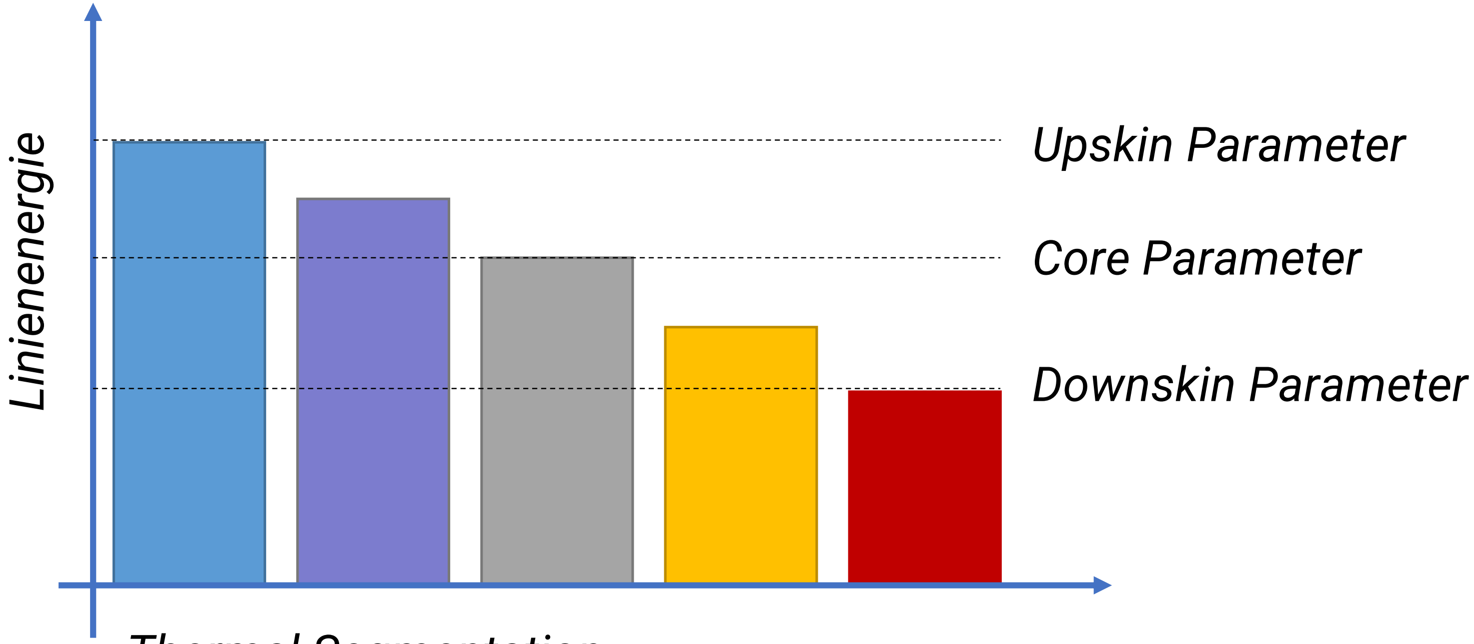
Automatic adatption of Power:
red = Core Power
White to blue = adapted power



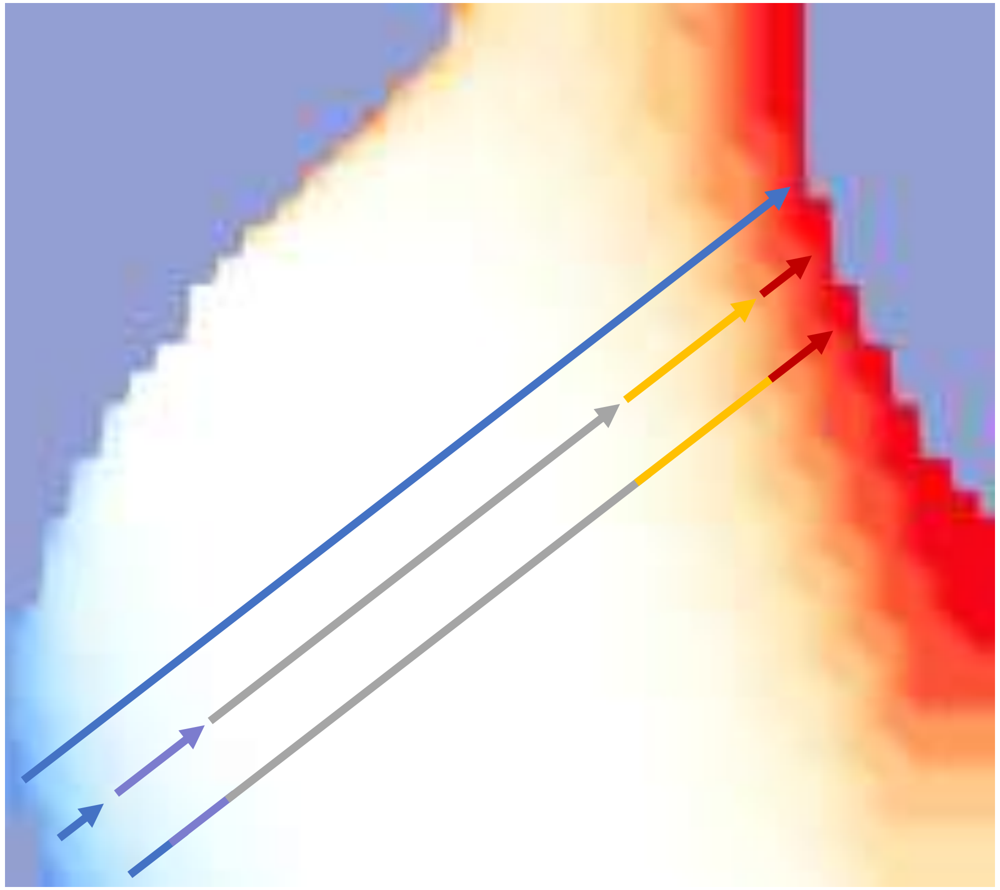
Development: Parameter Adaption Modul

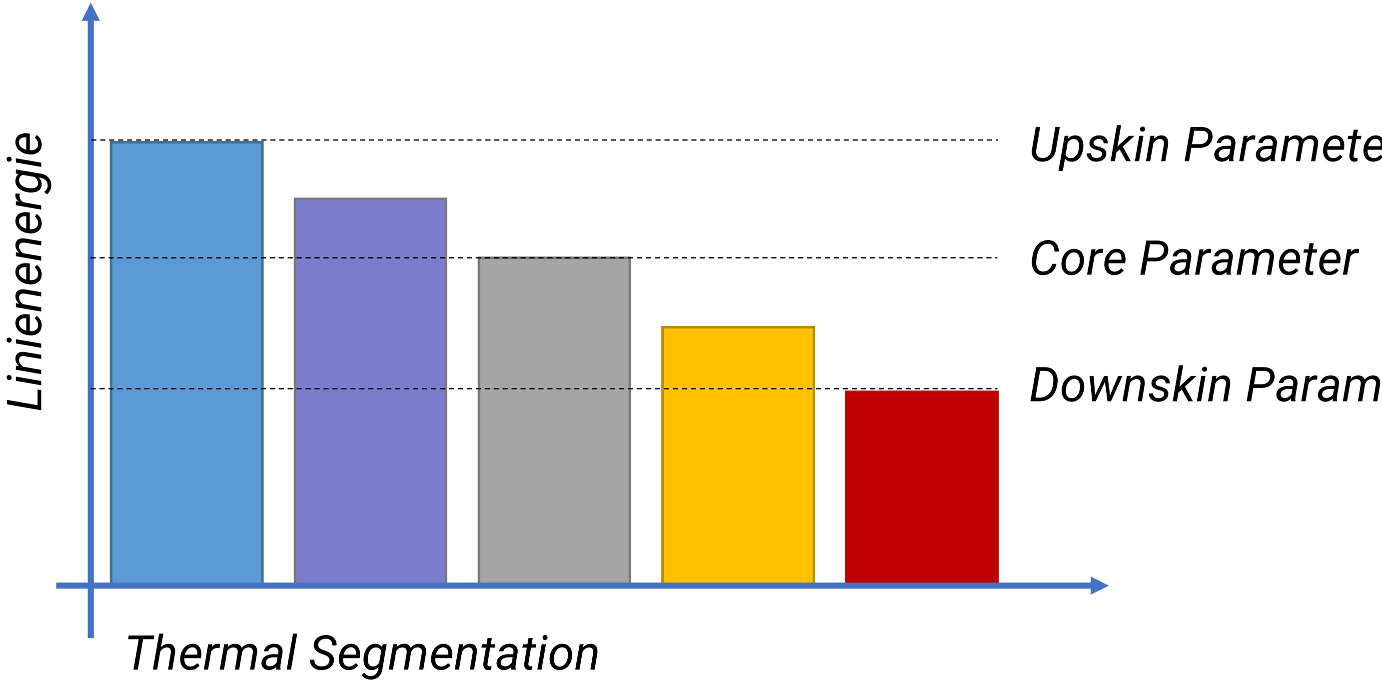


Parameter Adaption with conventional Hatching



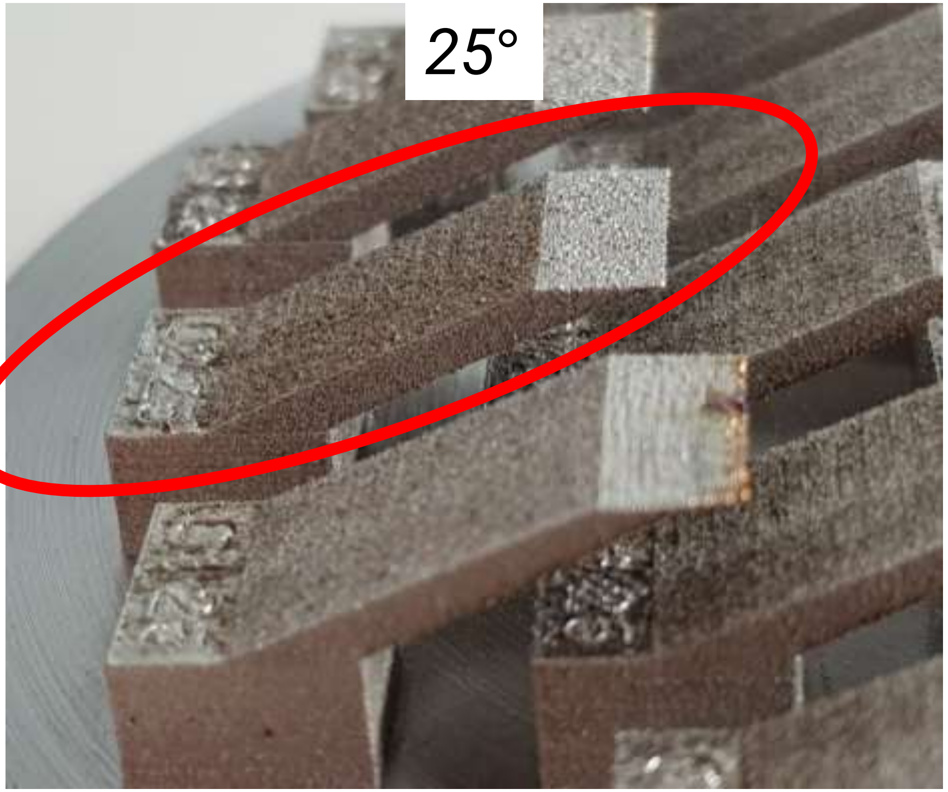
Development: Parameter Adaption Modul

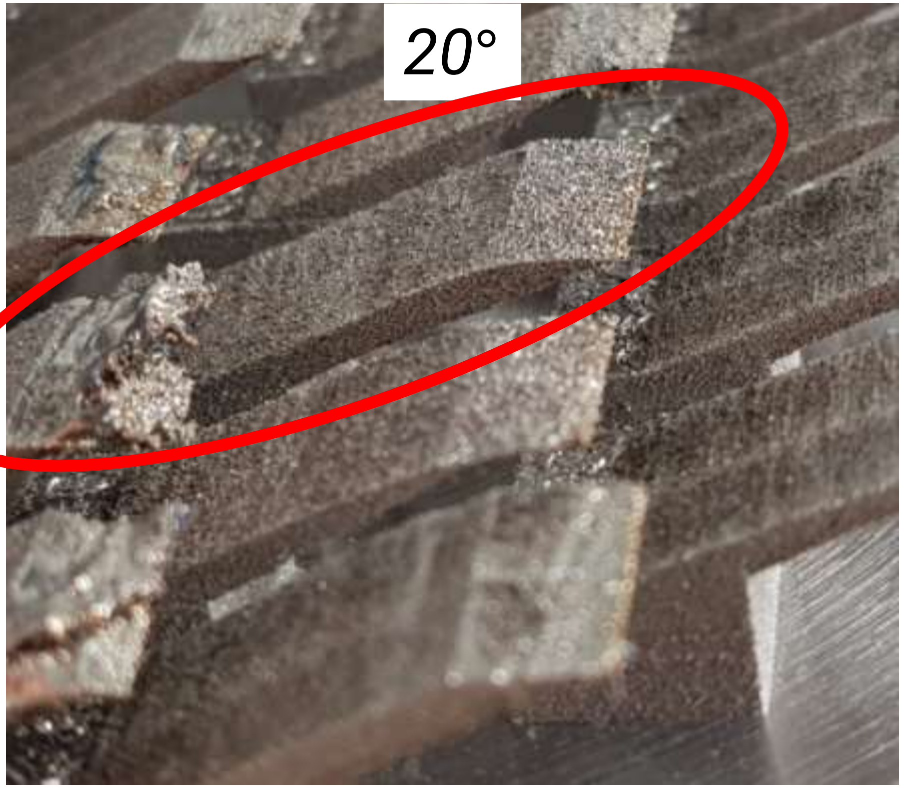




Development: Parameter Adaption Modul

- First results 316L





Summary & Outline

- *Simulationbased approach to adjust hatch orientation and sequence has been presented*
- *Distortion can be reduced*
- *Angles down to 20° could be printed in TI64*
- *Material Properties can be improved*

- *In future orientation and sequence will be combined with local parameter adaption*

Thank you for your attention

Dr. rer. nat.

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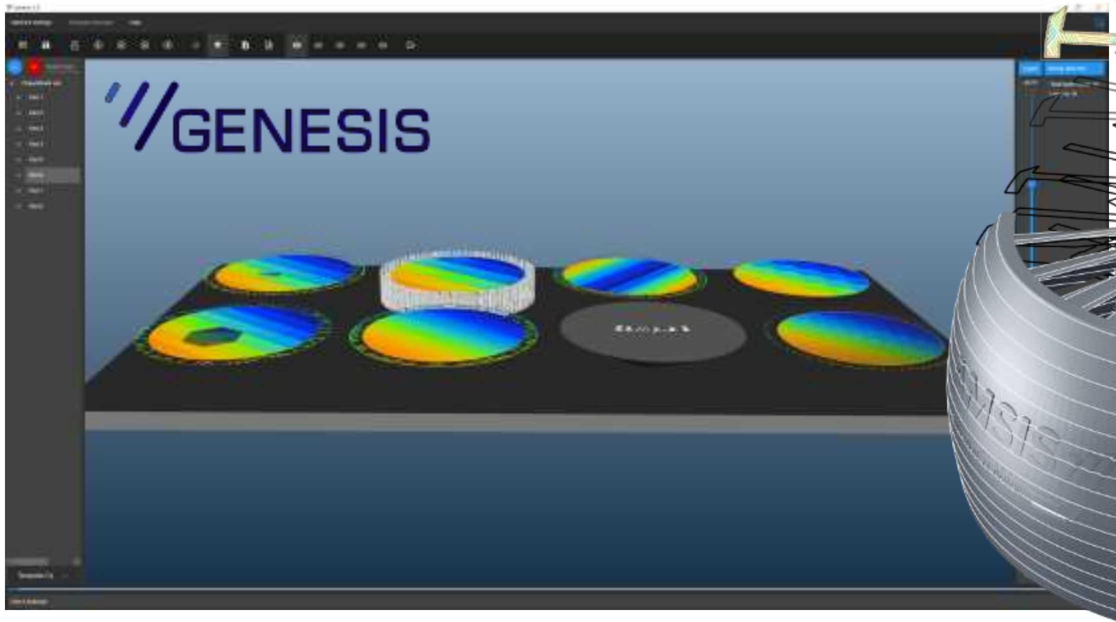
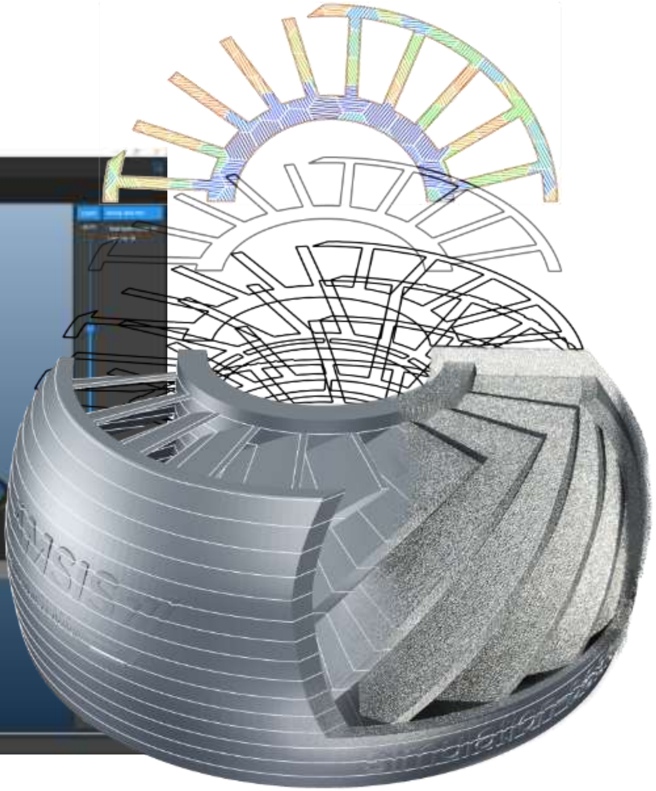
28359 Bremen

E-Mail: macke@amsis.de

www.amsis.de





Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1 **DAY 2**

public

Vertraulich

GRÜNDUNGSPREIS
GRÜNDUNGS WETTBEWERB
Bundesministerium für Wirtschaft und Klimaschutz
2022

3. Platz
GRÜNDER GEIST
2022

AI.STARTUP.HUB

Rotary
TUHH
Wissenschaftlichen Innovationspreis
2020

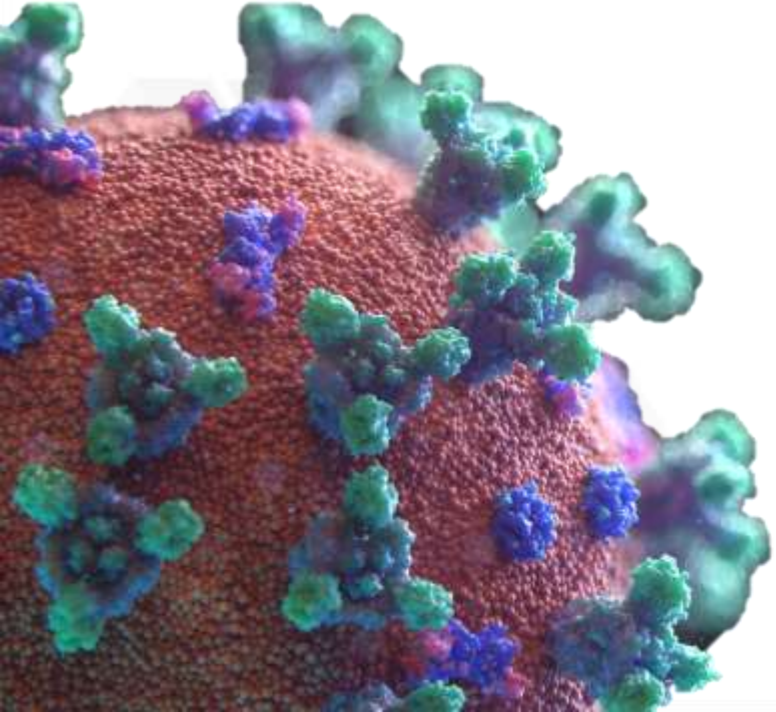
3D SPARK

The comparison engine for components

3D Spark GmbH Klaus-Groth-Str. 88 · 20535 Hamburg · Germany
+49 40 2263 6776-0 info@3dspark.de www.3dspark.de

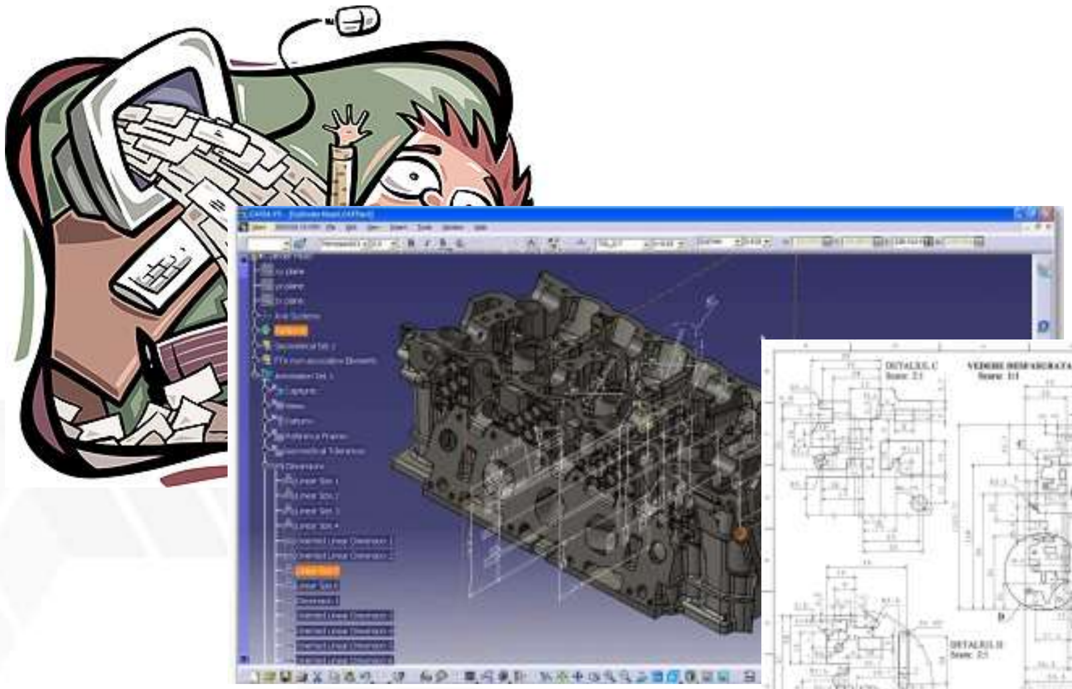
920.000.000.000,00 €

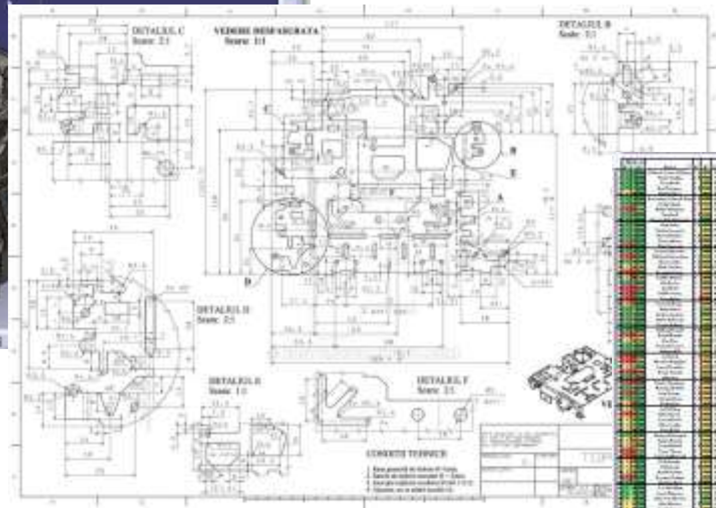
- Accenture – World Economic Forum 2022



3DSPARK

Challenges for 3D print shops: Quoting





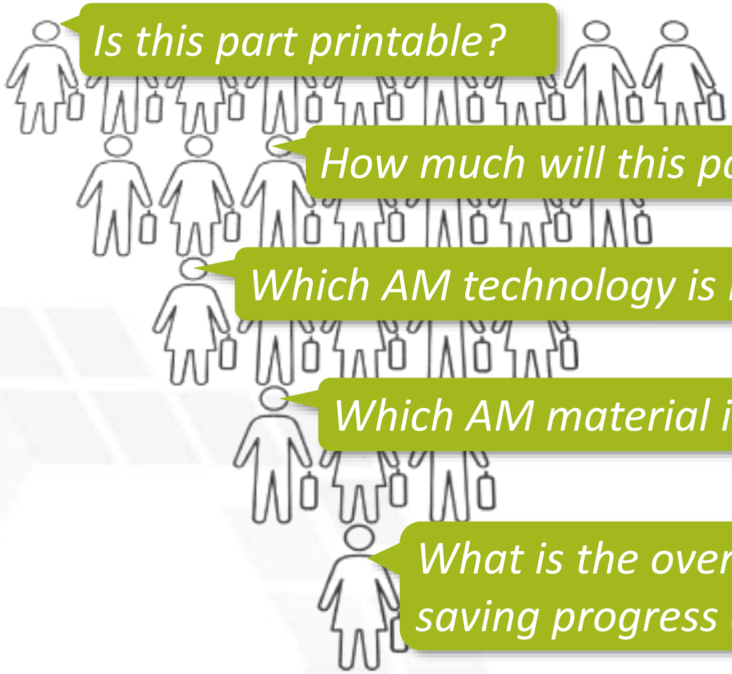
MetShape

„Quoting is so time consuming and annoying for me!“

Mike Schimmelpfennig

Head of Sales MetShape

Challenges for OEMs: Finding suitable Use-Cases



Is this part printable?

How much will this part cost if printed?

Which AM technology is best suited for my part?

Which AM material is best suited for my part?

What is the overall cost & lead time saving progress of our AM activities?

ALSTOM

„Making AM easily accessible for all of our employees is hard.“

Aurelien Fussel

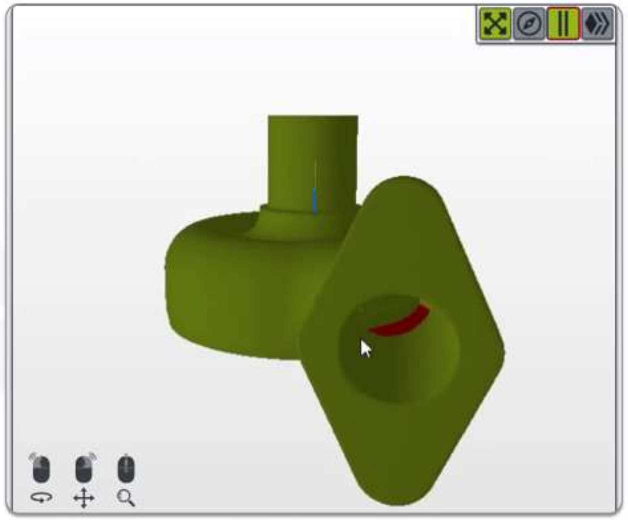
3D Printing Program Manager at Alstom

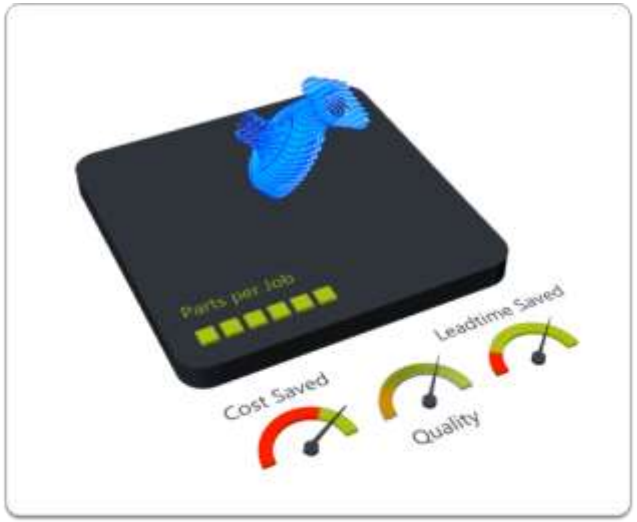
3D Spark – The Key to unlock hidden 3D printing Potentials

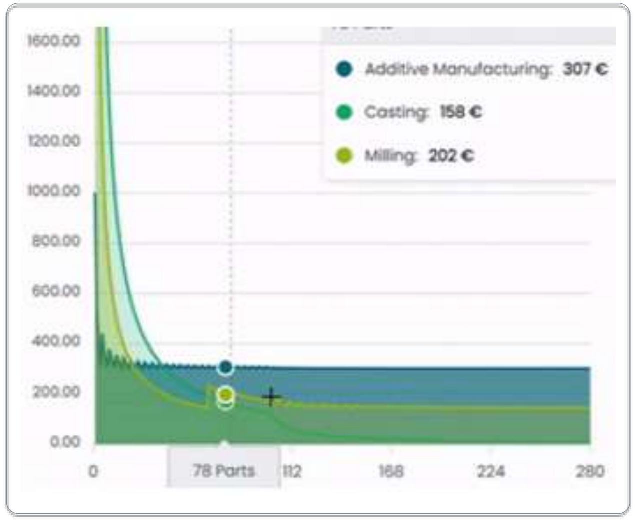
Printability Check:
Unique process know-how from 15 years of scientific research

Orientation Optimization:
Unique algorithm to minimize costs and delivery times

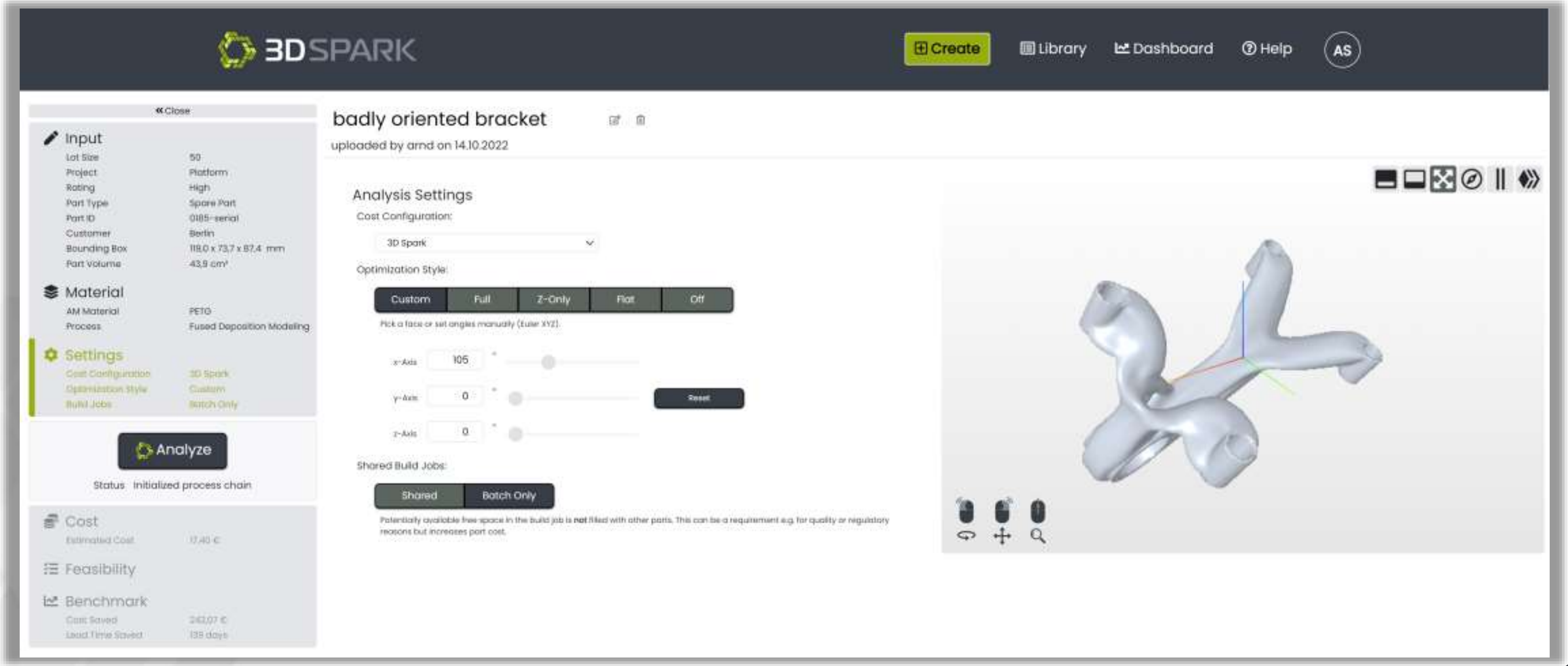
Break-Even-Analysis:
Unique training data set to specify the cost calculation



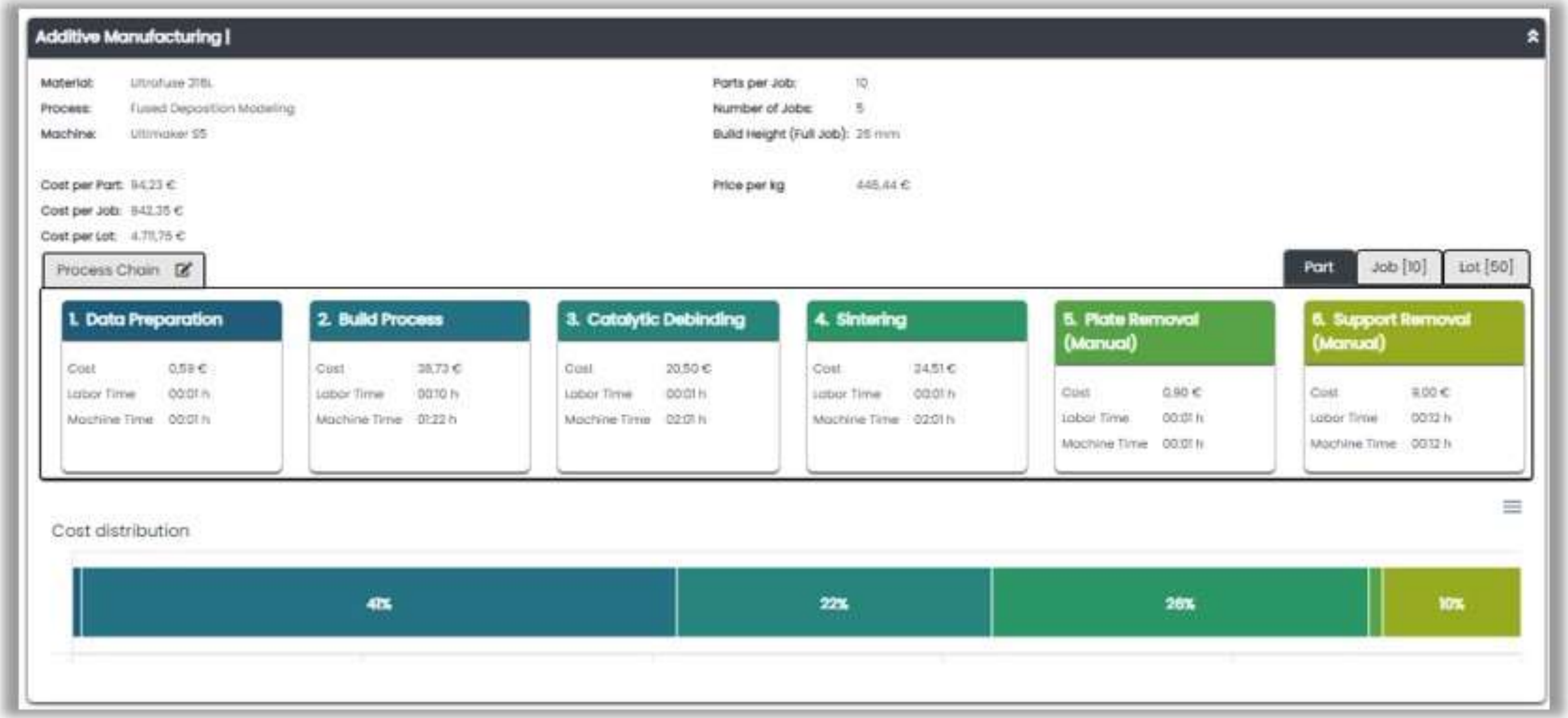




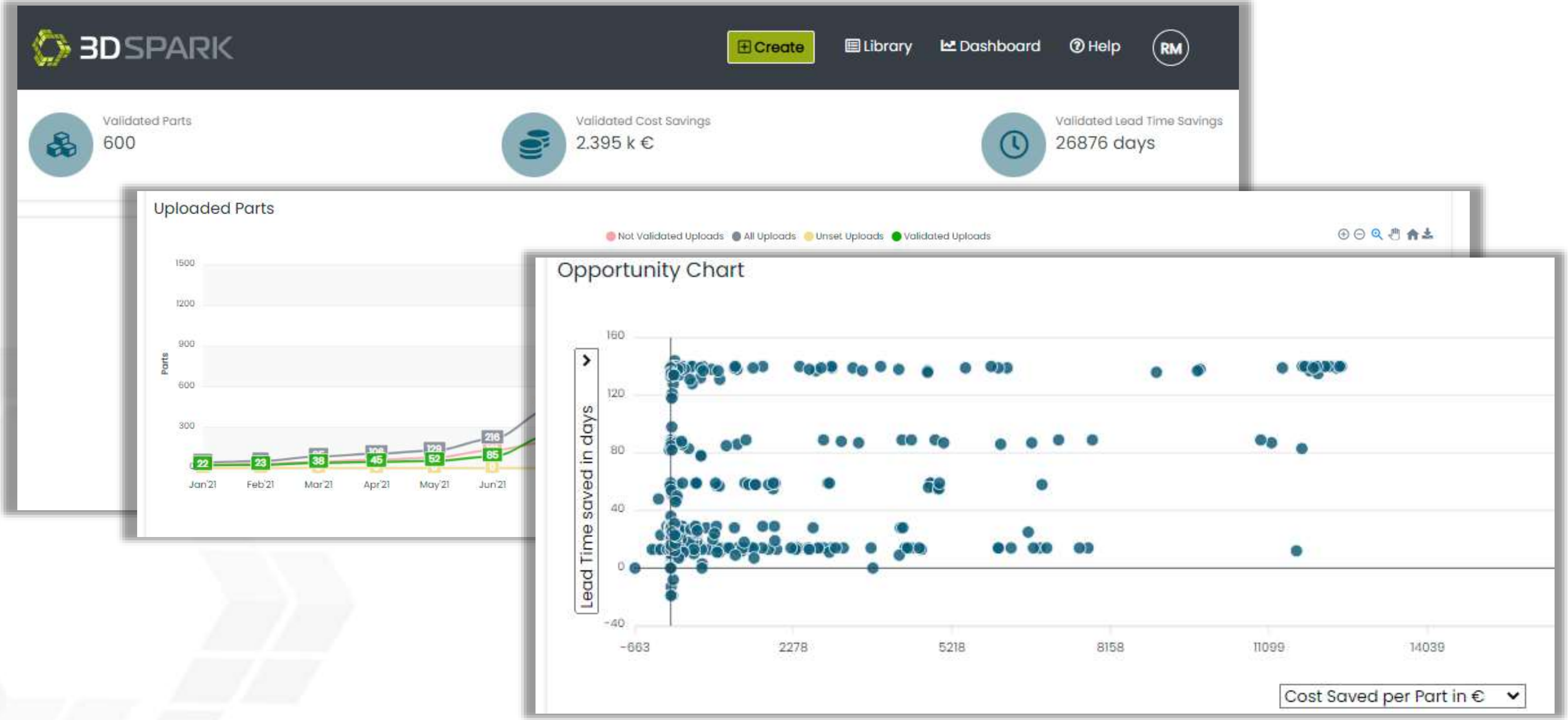
Analysis Settings for accurate results



Process Editor for quick cost fine tuning



Global overview of cost & lead time savings



Instant feasibility checks and quoting for 3D print shops

"The 3D Spark platform drastically reduces time and effort needed by my team to analyze 3D CADs and 2D drawings from daily Requests for Quotations (RFQs) regarding technical feasibility and precise, instant costing"

Mike Schimmelpfennig, Head of Sales at MetShape

Added value:

- >90% reduced quoting time
- 67% reduction of steps and tools needed for quoting
- 100% reduced effort for answering unsuitable RFQs

Finding suitable Use-Cases at OEMs

ALSTOM

"My mission is to ease the adoption of 3D printing at Alstom, and that's exactly what 3D Spark is helping us to do. We plan to triple the number of parts analyzed by the end of 2023, targeting cost savings of more than €5 million."

Aurelien Fussel, 3D Printing Program Manager at Alstom

Added value:

- 86% reduction of RFQs written by purchasing
- 24/7 consultancy and expertise growth support tool for all employees
- >20% reduction of parts purchase prices
- Global overview of cost & lead time savings

Successful application in Rail, Automotive and Manufacturing

Alstom saves €1.8M in costs, targets over €5M in cost savings by the end of 2023 thanks to 3D printing. Here is how.

In the rolling stock sector, train systems comprise a large number of individual moving parts. **Alstom**, a French rolling stock manufacturer operating in rail transport markets, operates multi-nationally and each of its trains has its own set of part requirements.

Since the very small batches require molds and other tooling, which lead to high upfront manufacturing costs and excessively long delivery times, the manufacturer relies on Additive Manufacturing to meet its production requirements.

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INDUSTRY

3D Spark wins startup award for successful cost saving at Alstom

By Lucia Gartner - Sep 2, 2022

Picture: 3D Spark

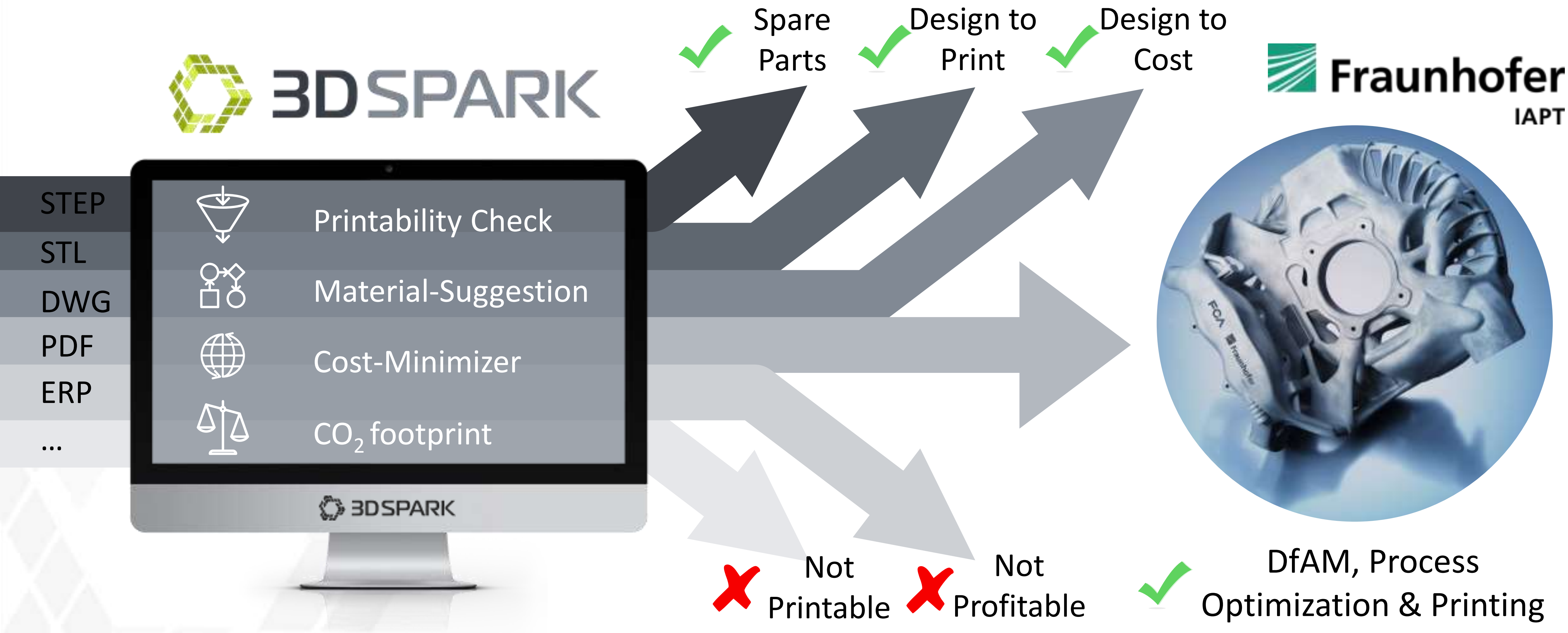
Startup 3D Spark saved 1.8 million euros in costs and 20,000 days in lead time with the world's second-largest railway technology company, Alstom, for which it is awarded a startup award.

As part of the summer round of the startup competition "Digital Innovations", the jury of the Federal Ministry of Economics and Climate Protection (BMWK) awarded 3D Spark with a startup prize of 7,000 euros as well as individual coaching. The official award ceremony took place on August 29, 2022 at the "Days of Digital Technologies" in Berlin.

> *"Millions of industry employees worldwide can make smarter decisions with the help of the 3D Spark platform, because they get the effects of different production alternatives transparently presented. This enables them to make a real contribution to more sustainable, crisis-resilient, and efficient production. We are thrilled that the BMWK is*

Big Data Part Screening

Get your entire product portfolio analyzed in one go!



18 years of research in application

Ruben Meuth
Co-CEO (external)

Dr.-Ing. Fritz Lange
Co-CEO (internal)

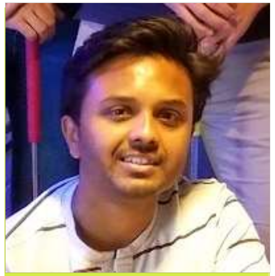
Dr.-Ing. Arnd Struve
CTO

Julia Lakämper
Product Designer

Tom Gensch
Backend Developer

Stephan Wiemann
Security Specialist

Ahmad Khalidi
Data Scientist



Sagar Lingaraj
AI Expert

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Bundesministerium für Wirtschaft und Klimaschutz
2022

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The comparison engine for components

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+49 40 2263 6776-0 info@3dspark.de www.3dspark.de

Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

Dräger

AM at Dräger – Sweet spots and challenges with focus on SLS

25. October 2022, Hamburg

Agenda

Item 01

Our markets and products

Item 02

AM at Dräger

Item 03

Sweet spots & challenges

Item 04

Conclusion & Outlook

01

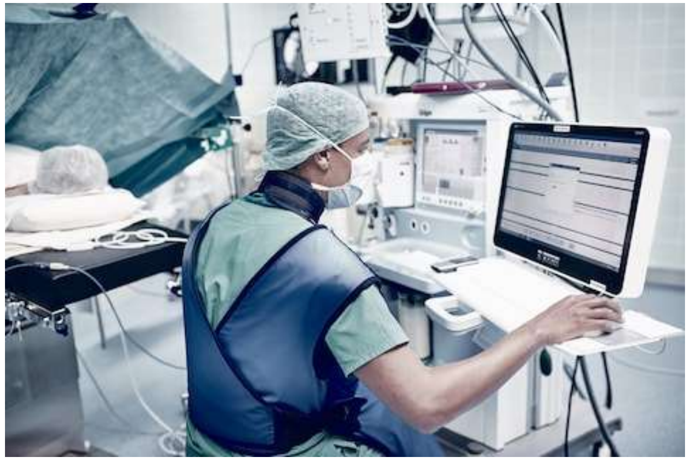
Dräger –
Markets and products

Dräger in profile

Figures from fiscal year 2021

Employees	15,900
Net sales	EUR 3328.4 million
Chairman of the Executive Board	Stefan Dräger (family-run)
Form of business organization	AG & Co. KGaA
Headquarters	Lübeck, Germany
Production sites	Germany, Chile, China, France, U.K., India, Sweden, South Africa, Czech Republic, U.S., Norway, Switzerland
Sales and service locations	In some 50 countries

Hospital portfolio



Safety portfolio

02

AM at Dräger

Machine park (SLS)

2 x EOS P396 SLS printers

Unpacking

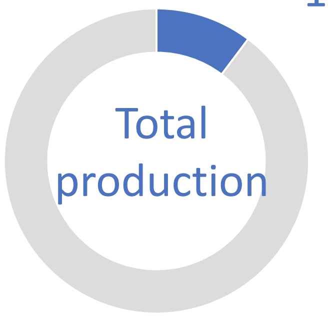
Depowdering

Surface homogenization

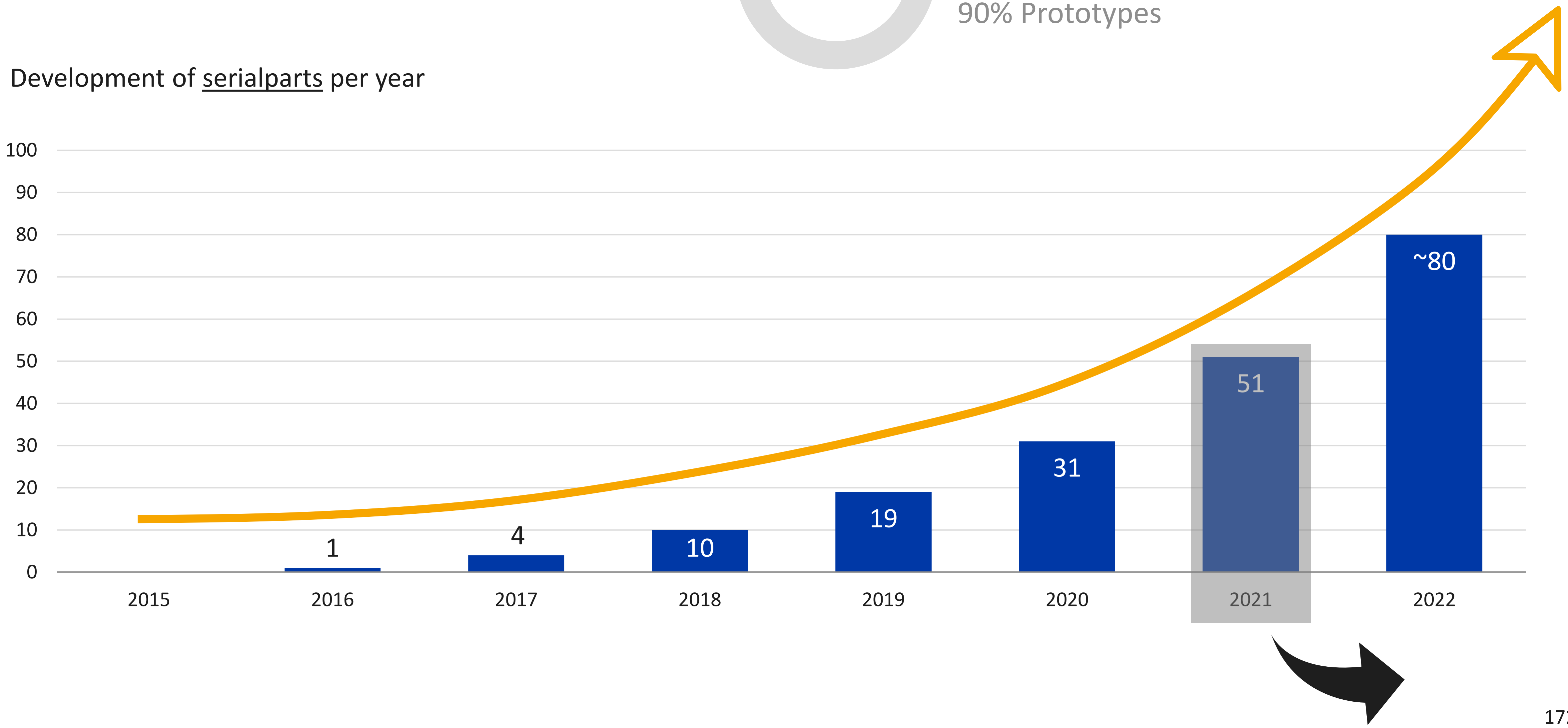
Coloring

+ Vapor smoothing machine from Nov. 2022

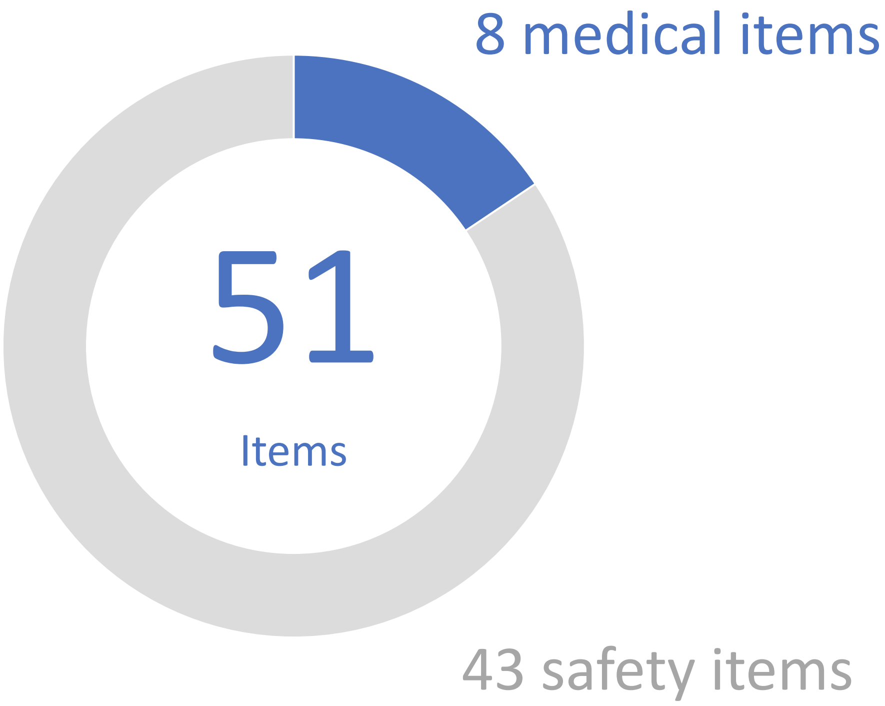
Production

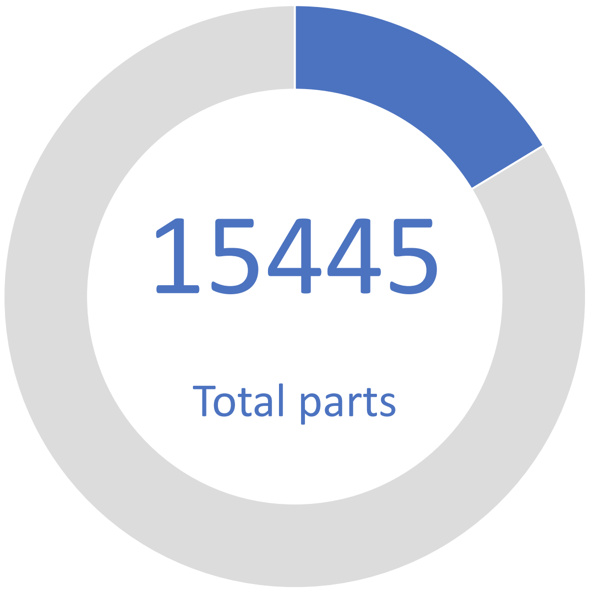


Development of serialparts per year



Insights of Dräger AM serial part production (2021)





Highest quantity per item:
2500 pcs./year

Serial parts Examples

Quaestor 6/8000
Pipe fixation

400 pcs./year

LAR 8000 LDV
Service tool

50 pcs./year

Perseus A500 PAGSS

100 pcs./year

BG ProAir
Training adapter

250 pcs./year

03

Sweet spots & challenges

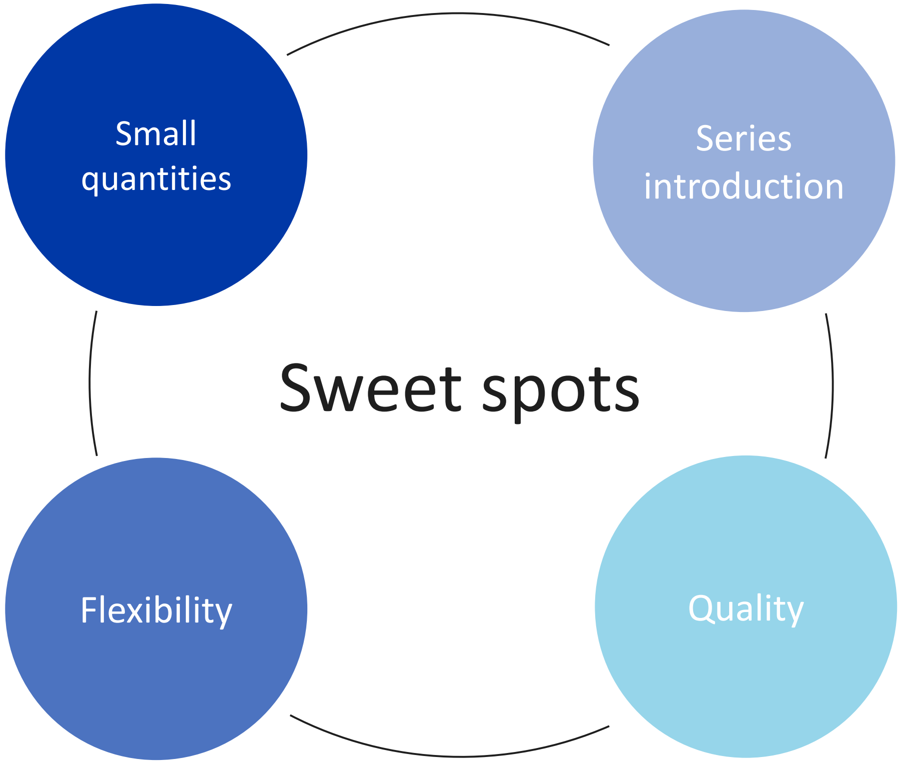
Sweet spots of internal SLS production

Serial products with small/medium quantities

- Quantities starting from 20 pcs./year

Fast series introduction

- Series introduction within 3-4 weeks possible



Fast changes and flexibility in production

- We can respond more quickly to urgent orders and implement changes to parts faster

Quality of <u>internal</u> SLS production

- With our SLS printers, we can achieve higher tolerances than our suppliers can guarantee us

Challenges for AM parts

Particle cleanliness

To be able to use AM parts in breathing circuits or medium pressure pneumatic applications, the parts must have different levels of cleanliness regarding particles.

Sealing function

~ 95% of our products have a gas-conveying function. Therefore, functional AM parts must have good surface quality for sealing in most cases.

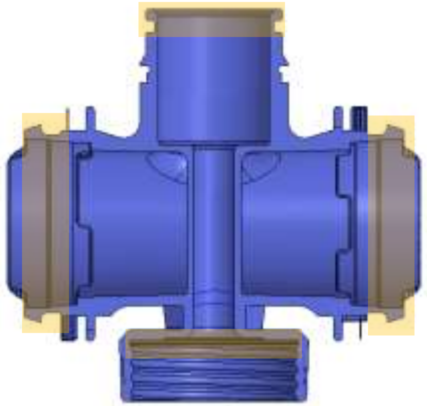
Cleaning and disinfection

Materials and surfaces must be suitable and resistant for cleaning and disinfection agents.

Example: BG-Pro AIR training adapter

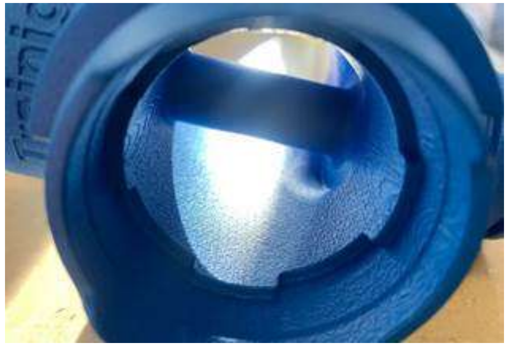
BG-Pro Air (CCBA – closed circuit breathing apparatus)

Challenges during development



Sealing surfaces

+



Particles

+

Color change

→

- No sealing possible up to 100mbar

- Inner cavities were difficult to impossible to fully depowder
- Easy to remove particles from rough surface

- Color change because of exposure to cleaning & disinfection agents

Vapor smoothing has a high potential to solve these issues

04

Conclusion & Outlook

Conclusion

- High time savings due to in-house production
- High flexibility in serial production
- Higher quality and lower costs of internally produced SLS parts

Outlook

- Vapor smoothing has high potential for increasing the quality & functionality of our serial parts
- Besides SLS we look into MBJ and LPBF

Many thanks

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23560 Lübeck, Germany

Tel. +49 451 882-4144
Mail carl-christoffer.neumann@draeger.com

Contact me on LinkedIn!

Dräger. Technology for Life®

Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

Production of the future: Additive Manufacturing for ZF ::AM4ZF::

Dr. Lobo Casanova | SMART Lightweight | Corporate Production

Agenda

1. Speaker Introduction
2. ZF Friedrichshafen AG / Corporate Production Strategy
3. Production of the future: Additive Manufacturing @ ZF

01
Speaker Introduction

IGNACIO Lobo-Casanova

1 min introduction

1979
Born December. 22, 1979 in Zamora, Spain
married, two children

2001
Engineer: Industrial Mechanics & Engineering
University of Burgos – Burgos (Spain)

2003
Master's Degree in Advanced Studies of Materials Science
University of Salamanca – Salamanca (Spain)

2003
Project Engineer Advanced Development (Product & Manufacturing Process)
ZF Ansa Lemförder S. L. – Burgos (Spain)

2007
Project Engineer Advanced Development (Product & Manufacturing Process)
ZF Lemförder GmbH – Dielingen (Germany)

2010
Doctor Engineer in Materials Science & Engineering
„Research and development of the hybrid technology for Chassis parts – Hybrid Control Arm –"

2011
Expert Advanced Manufacturing (OPYA: Corporate Production)
ZF Friedrichshafen AG – Friedrichshafen

2013
Head ZF Composites Tech Center (OPYA: Corporate Production)
ZF Friedrichshafen AG – Friedrichshafen

2020
Head of SMART Lightweight Process Technologies (EOWL: Division E)
ZF Friedrichshafen AG – Friedrichshafen

02

ZF Friedrichshafen AG / Corporate Production Strategy

ZF Friedrichshafen AG

ZF Technology Domains

ZF Friedrichshafen AG
Financial Overview 2021

EUR 38.3 billion
sales

157,549
employees

EUR 3.1 billion
Research & Development

EUR 1.9 billion
adjusted EBIT

5.0%
adjusted
EBIT margin

EUR 1.6 billion
investments in
property, plant,
and equipment

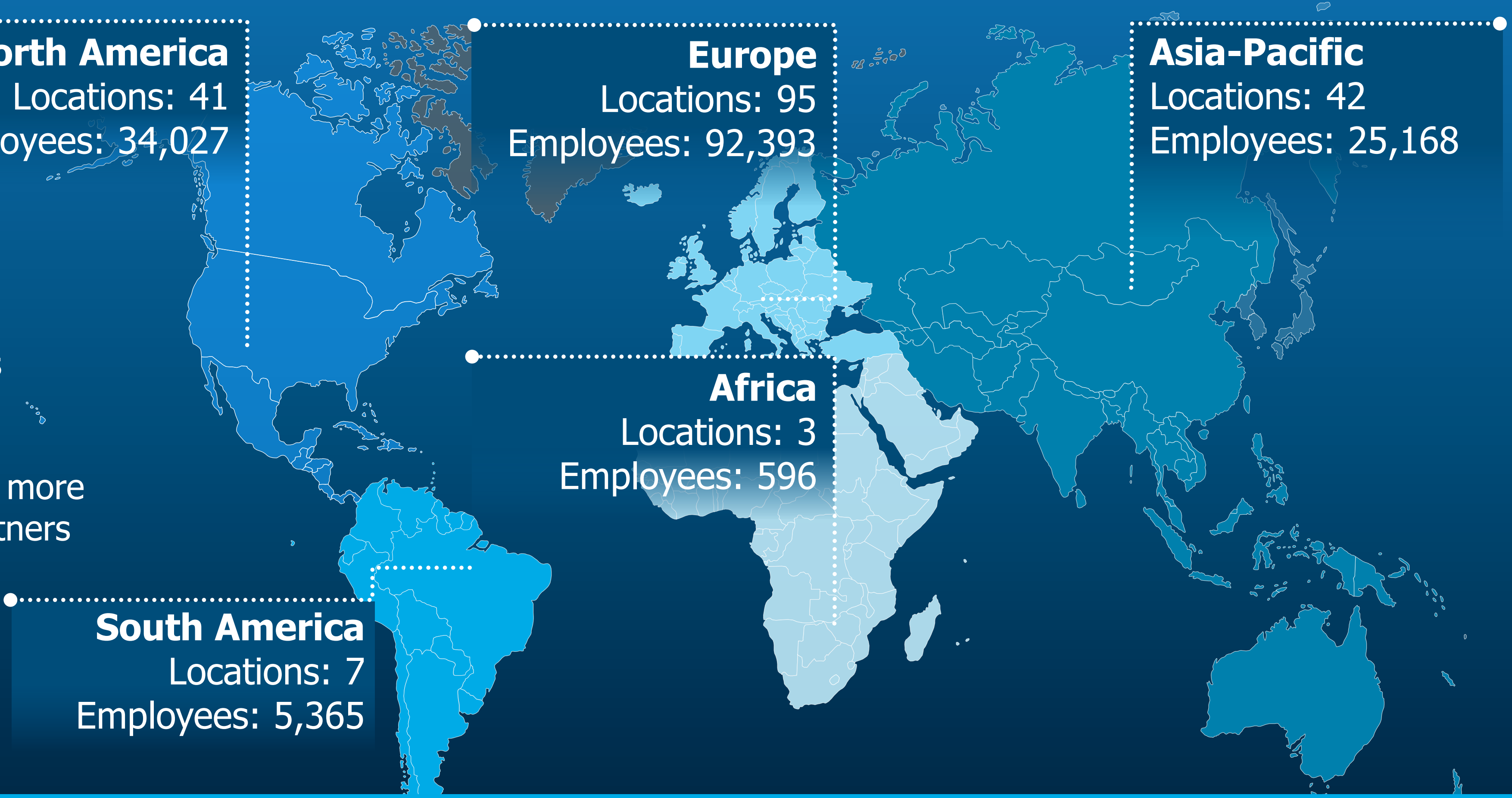
ZF Friedrichshafen AG

Key Figures – Locations

188 production locations in **31** countries

18 main development locations in **8** countries

Global service network with more than **15,000** workshop partners



Worldwide Presence – Production, Development, Sales and Service

ZF Friedrichshafen AG

Strategy Production Technology / Center of Excellences (CoE)

Production Network / Center of Excellences

Production Technology Development

(1) Technologies **w/o** product impact

- **Robotics**
- **AGV**
- **Vision Systems**
- …

(2) Technologies **with** product impact

- **Additive Manufacturing**
- **Composites**
- …

Support Process Production

(3) Processes **w/o** regional dependencies

- **Maintenance**
- …

(4) Processes **with** regional dependencies

- **Work & Safety**
- …

Production Network/ Center of Excellences (CoE)

Major Tasks of CoE's | Close Loop Approach

Production Technology Development

(1) Technologies **w/o** product impact

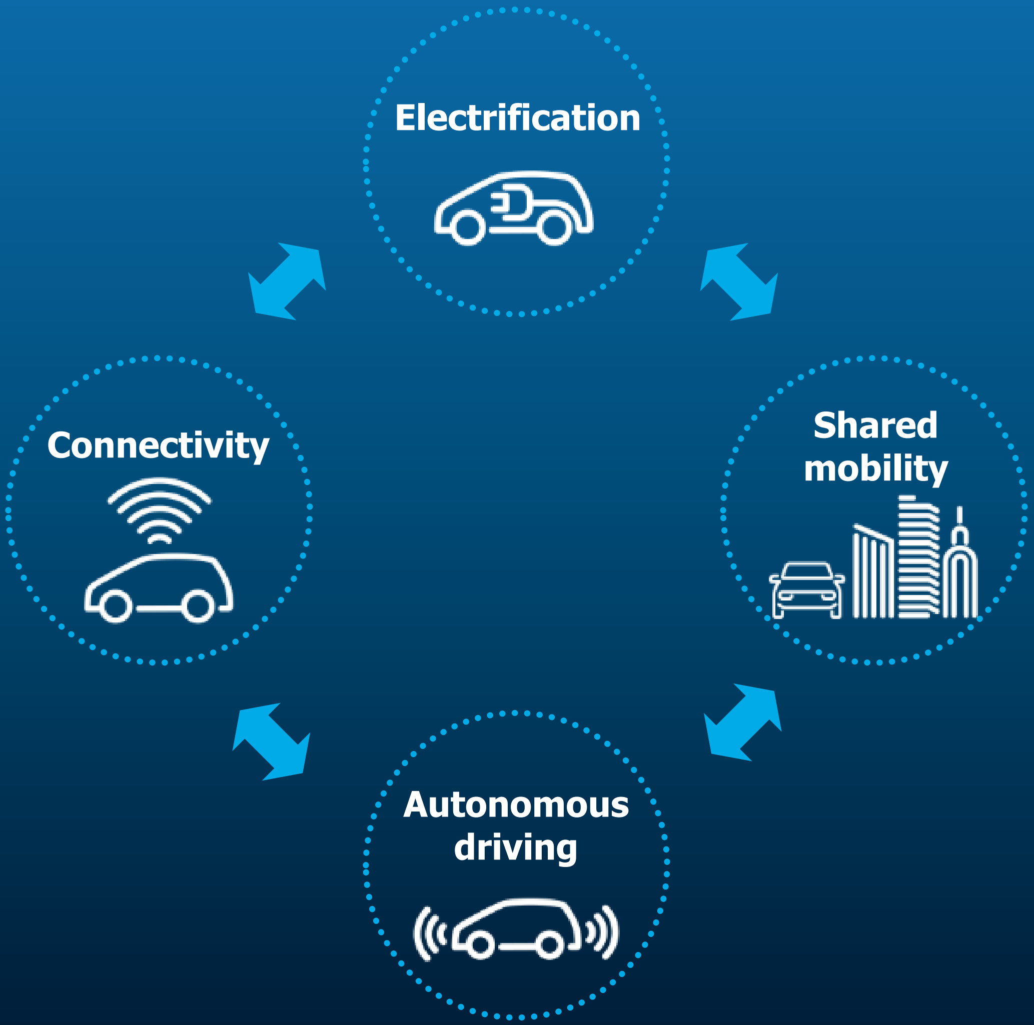
(2) Technologies **with** product impact

without	Functions	with
✓	Production Technology Development	✓
✗	Material Development	✓
✗	Product Development (Design & Simulation)	✓
✗	Quality Development / Assurance	✓
✓	Purchasing	✓
✓	IT	✓

03

Production of the future: Additive Manufacturing @ ZF

Disruptive Automotive Trends



Radical changes in the automotive industry

- Changes in **mobility behavior**
- **Diffusion** of advanced **technology**
- **New competition** and **cooperation**
- **Shifting markets** and revenue pools
- Digitalization in **products & processes**

Additive Manufacturing…

…a Disruptive Technology for the Disruptive Automotive Trends

Create CAD Model

Convert to .stl file and slice Model

3D Printing Process

Post Processing

Finished Part

Additive Manufacturing is a Disruptive Technology

AM Production technologies enable **new products design/functionalities**

Change in **how products are designed, produced** and **delivered**

Product and production data is digital available and can be **manufactured everywhere** (global production network)

Change of **value chain** (production, logistic, quality, spare parts management, etc.)

Change of **supply chain** and **know-how-transfer**

Economical production with lot size "one"

ZF Approach: Additive Manufacturing

Structure: ZF Team Additive Manufacturing

3D

Information Portal

Expert-Team AM

cross-divisional and interdisciplinary (Development, Production, Purchasing, etc.)

- **Projects Use-Cases**
- **3D Printing Network**
- **Know how Exchange**
- **Information Platform**

Point of contact:
Dr. Lobo-Casanova, Ignacio

ZF Approach: Additive Manufacturing

Topics: Use Cases and Cross-Functional Activities

AM Substitution Approach
one-to-one-copy manufactured by AM technology

AM Design Approach
embedded functions and optimized designs

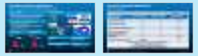
Machine Spare Parts

- Reduction of costs for provision and maintenance of tools
- Reduction of storage costs and logistics costs
- Print-on-Demand

Tools and Fixtures

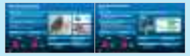
- Shortening of production time
- High degree of flexibility
- More powerful tools possible (e.g. near contour tempera-ture control)

Functional Prototypes



- Earlier validation in the development phase possible
- Reduction of costs for optimization loops
- No tooling needed / short delivery time

Serial Parts & Aftermarket



- Innovative products (lightweight, highly complex geom., function integration…)
- Profitable for <10 T units (no tooling, less product. steps, less assembly)
- Aftermarket: Reduction of storage and logistics costs

Cross-functional Activities / AM-Fundamentals

Technology Benchmark	**Material Development**	**CAD-Tools Dev. “Design-Rules”**	**Simulation Tools Develop.**	**Quality Management**	**Work Health and Safety**
IT-Integration “AM Marketplace”	**Coordination AM-Prod. Network**	**Purchase activities**	**….**	**….**	**….**

Functional Prototypes Applications

Sensor integration in occupant safety system

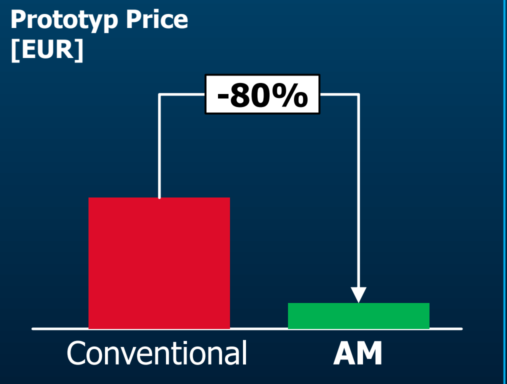
Project Goals

- Use of 3D printing technology to develop a new sensor implemented in safety systems (e.g. force data as an input for electrical controlled restraint systems)

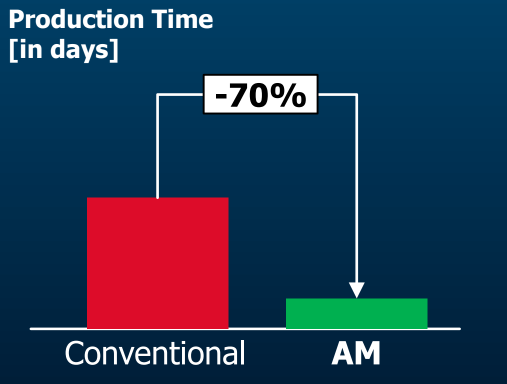
AM – Approach / Description

- SLS or SLA Technology (PA12)
- 10 different geometries printed und tested to develop basic principles of new sensor technology and its behavior (feasibility study)
- Plastic injection tool not needed for first prototypes

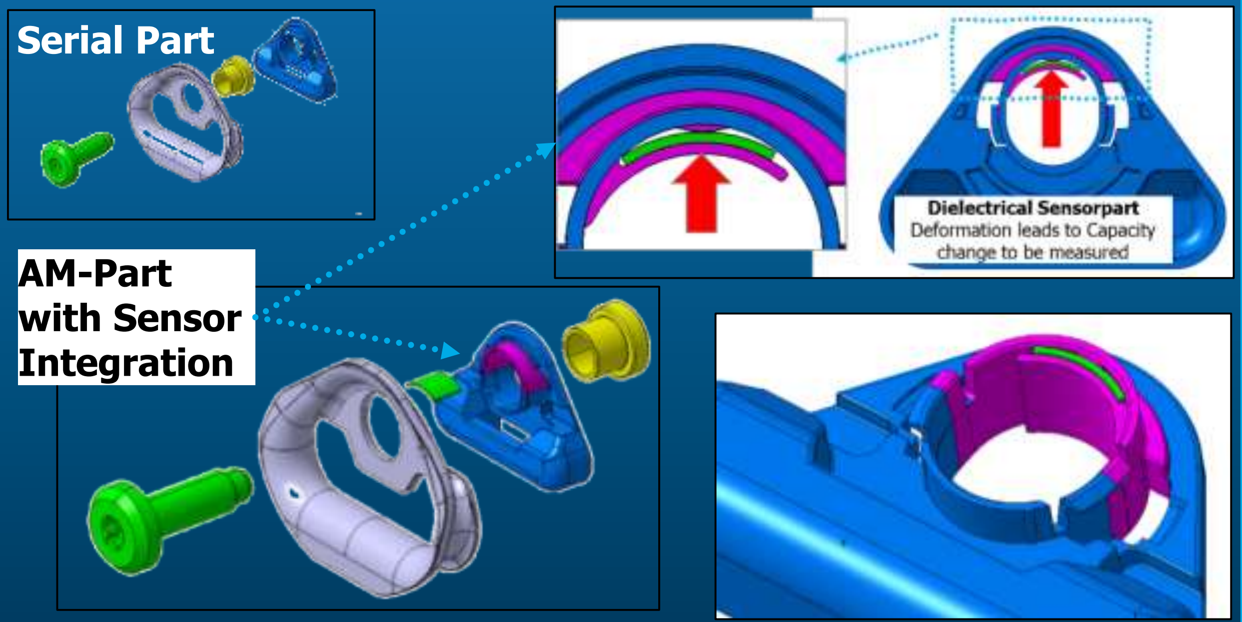
Cost Saving



Time Saving



3D Printing Parts



Customer

R-Div.

AM Manufacturer

Prod. HUB Plastic FRD

Status/Implemented

Closed

Use-Case:

Functional Prototypes

Functional Prototypes Applications
Lessons learned

(Rating Scale: ++/+/0/-/--)

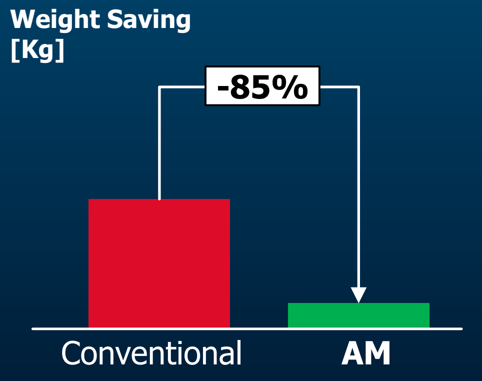
R&D Prototypes Requirements	AM Cost Savings	AM Time Savings	AM Part Quality
Metal Casting Design	++	++	+ or 0
CNC-Machining Design	0	+	+
Plastic Inject. Moulding Design	++	++	0 or -
Sub Parts Welding Design	++	++	0
Experimental Design Validation	++	++	+ or 0
No Early Supplier Assignment	+ in series	+	n/a

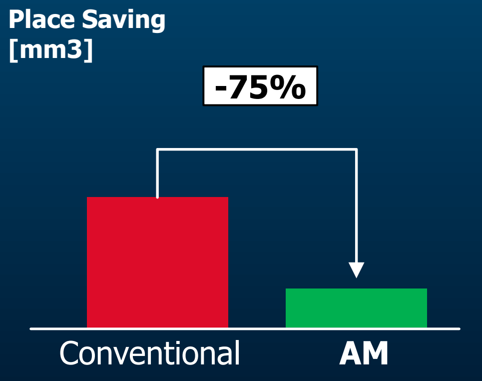
AM-Technology offers big COST and TIME savings,
if designs with Tooling technologies
or if more Prototype design loops are needed

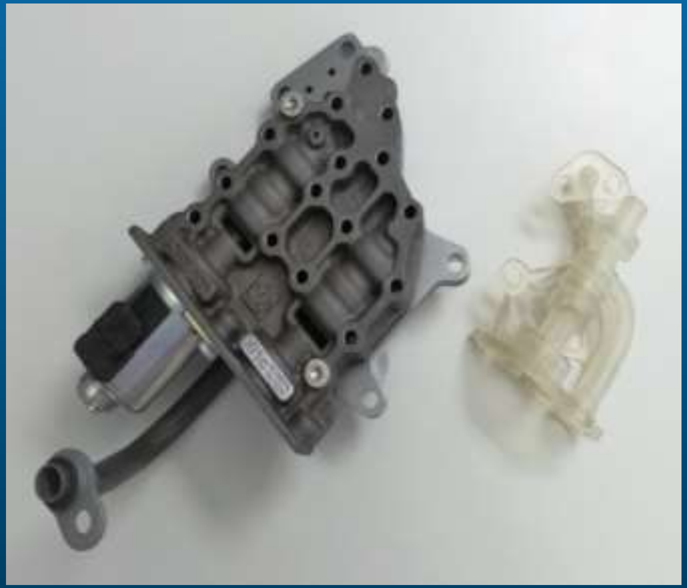
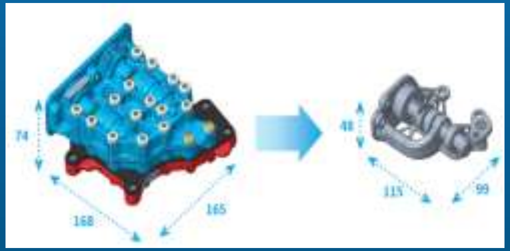
Serial Parts Applications
Hydraulic Valve Control Unit

Project Goals
- Development of an additive manufactured valve unit
- Function integration / Weight and installation place saving

AM – Approach / Description
- Plastic Prototypes (SLA) for packaging studies and oil-flow analysis
- Metal Prototypes for final validation

Weight Saving


Place Saving


3D Printing parts (before/after)




Customer
R&D AM4ZF

AM Manufacturer
Prod. HUB Plastic FRD
Prod. HUB Plastic PLZ

Status/Implemented
Study 2020
(not implemented)

Use-Case:
Functional Prototypes

Serial Parts Applications

Sound AI

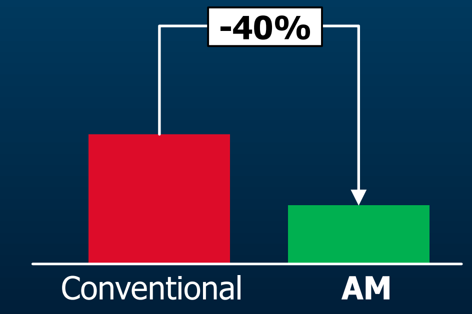
Project Goals

- **Improve Sound-AI Performance / Functionality**
- **Avoid tooling cost and reduce development time for small series application**

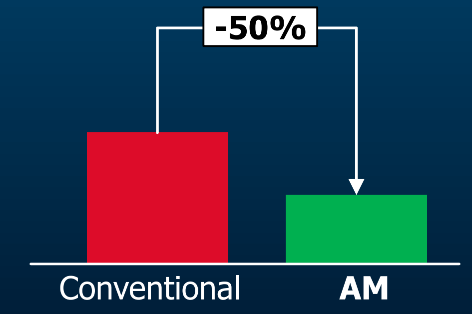
AM – Approach / Description

- **AM Design for the components** (from 3 plastic injected part to 1 additive manufactured part)
- **Plastic housing made of PA12 in SLS technology**
- **AM Design offer other possibilities for further function-abilities** (heating/cooling channels, airflow optimization, etc.)

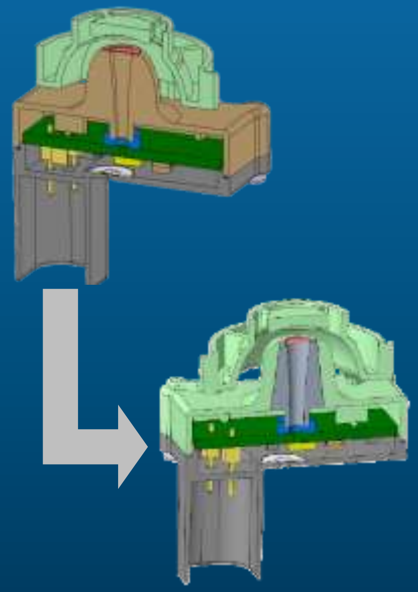
Cost Saving

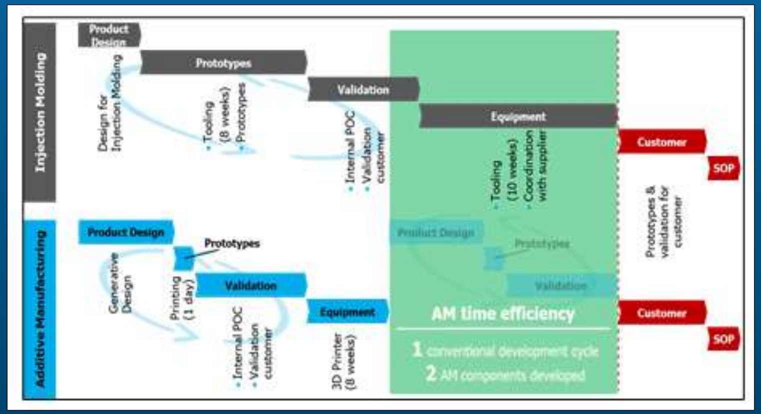


Time Saving



3D Printing parts (before/after)





Customer

FRD / Prod. Hub

AM Manufacturer

Prod. HUB Plastic FRD

Status/Implemented

Study 2019 / 2021
(not implemented)

Use-Case:

Serial Parts Study

Thank you

Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

Miniatur Wunderland Hamburg GmbH

Kenneth Mandel
&
Mathias Stamm

founded: 16.08.2001

Today:

> 420 Employees

> € 36 mio construction costs

> 1,4 mio guests / year

The thing on the wheel

>120 computer controlled cars

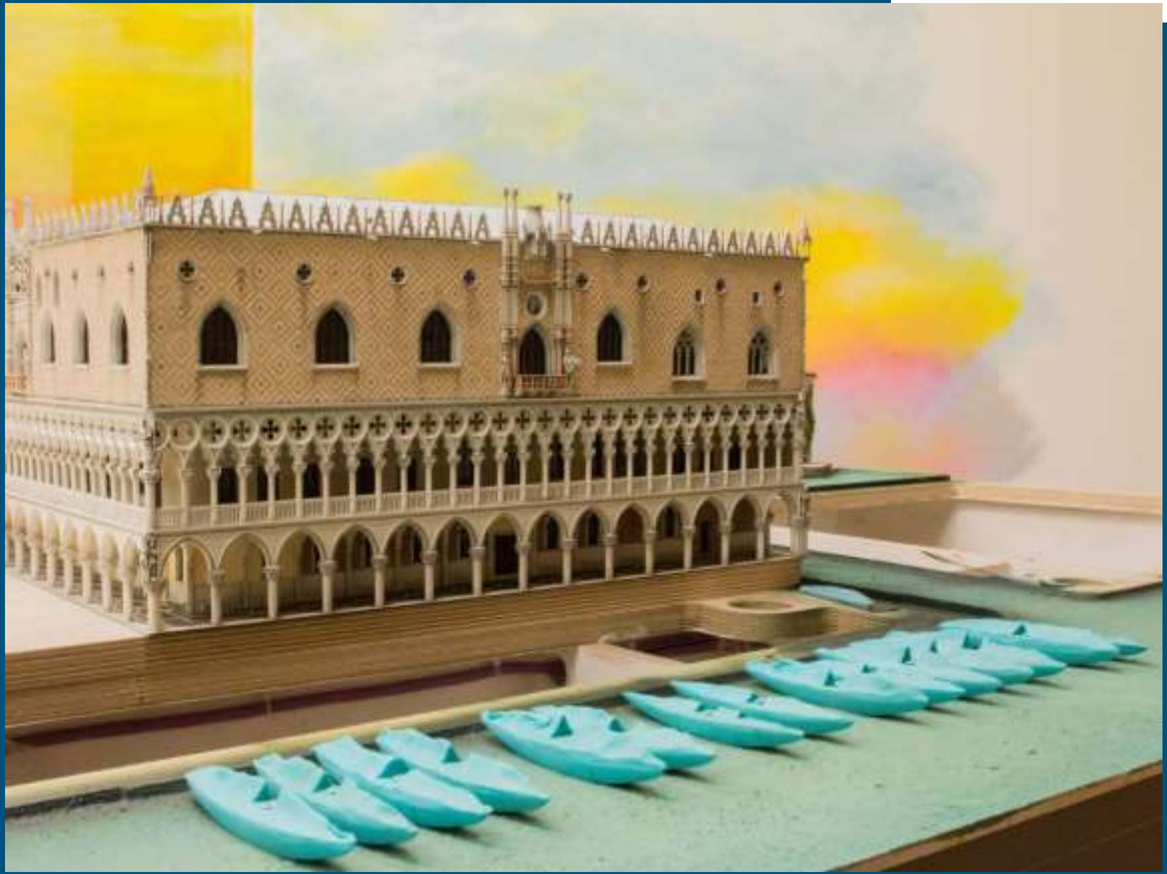
ALL hand-built

to break a Butterfly on a wheel

since 2006 CNC-milling

First touch of 3D printing in 2012

4 years later using 3D-printers in house



“Let’s start to 3d print something.”

What should the printer be?

figurines or freeform?

Who will operate the printer?

co-workers or model builder?

What should the room look a like?

storage / cleaning / exhaust air?

Overall we need

any *3D-printing technology,*

which is available:

- *Printing figurines (3D Fullbody scan)*
- *Architecure (Elbphi windows)*
- *mechanics*

The extra ordinary choice principles for 3D Printing

The 3D projects

Miniatur Wunderland HAMBURG

2014

Elbphilharmonie

2016

Italien

202X

Visitors

Formula 1 Cars

Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez

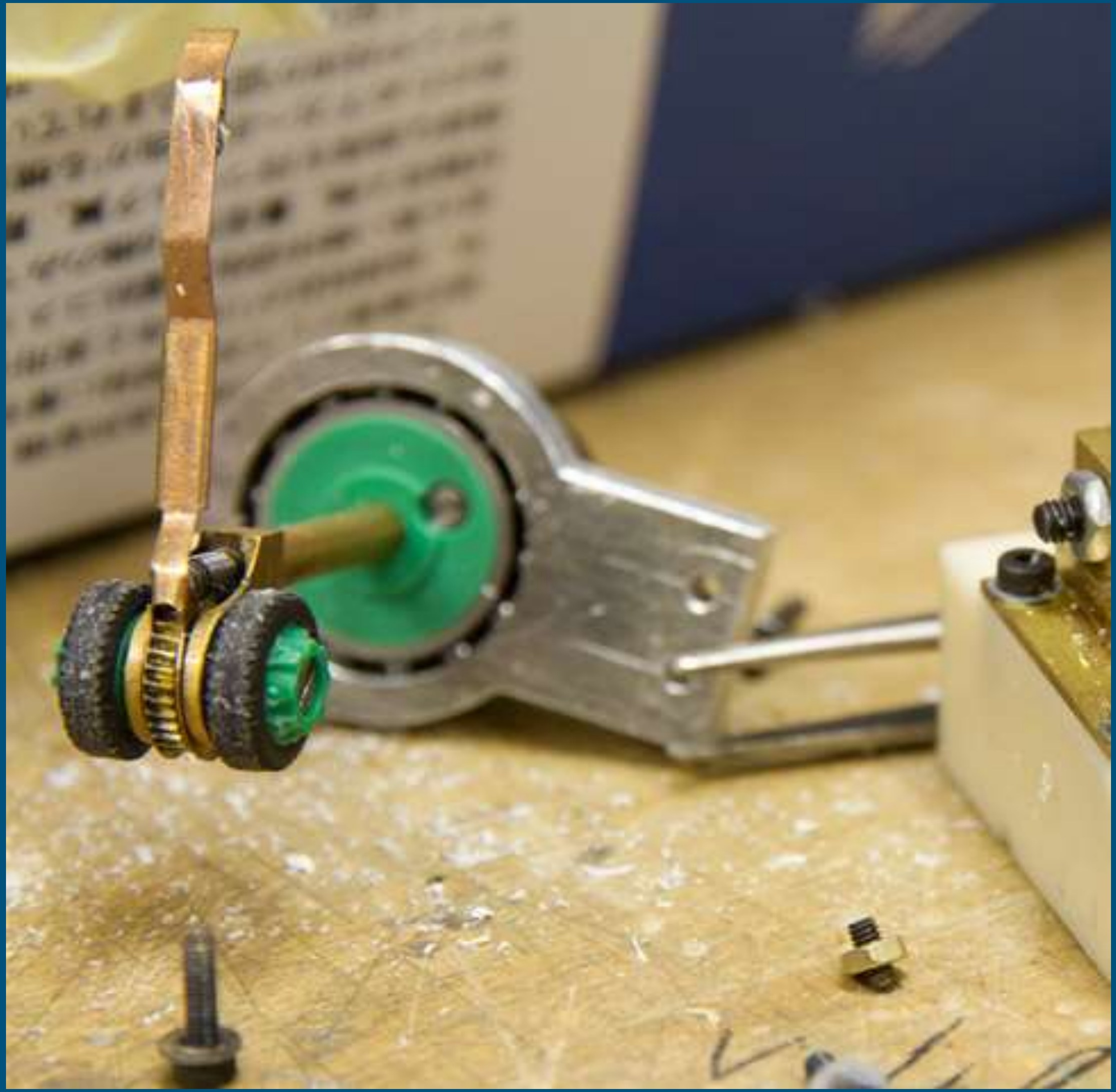
2015

Olympia Stadion Berlin

Farbenspiel Bühne

2018

Venice



Aircraft nose wheel

Miniatur
Wunderland
HAMBURG

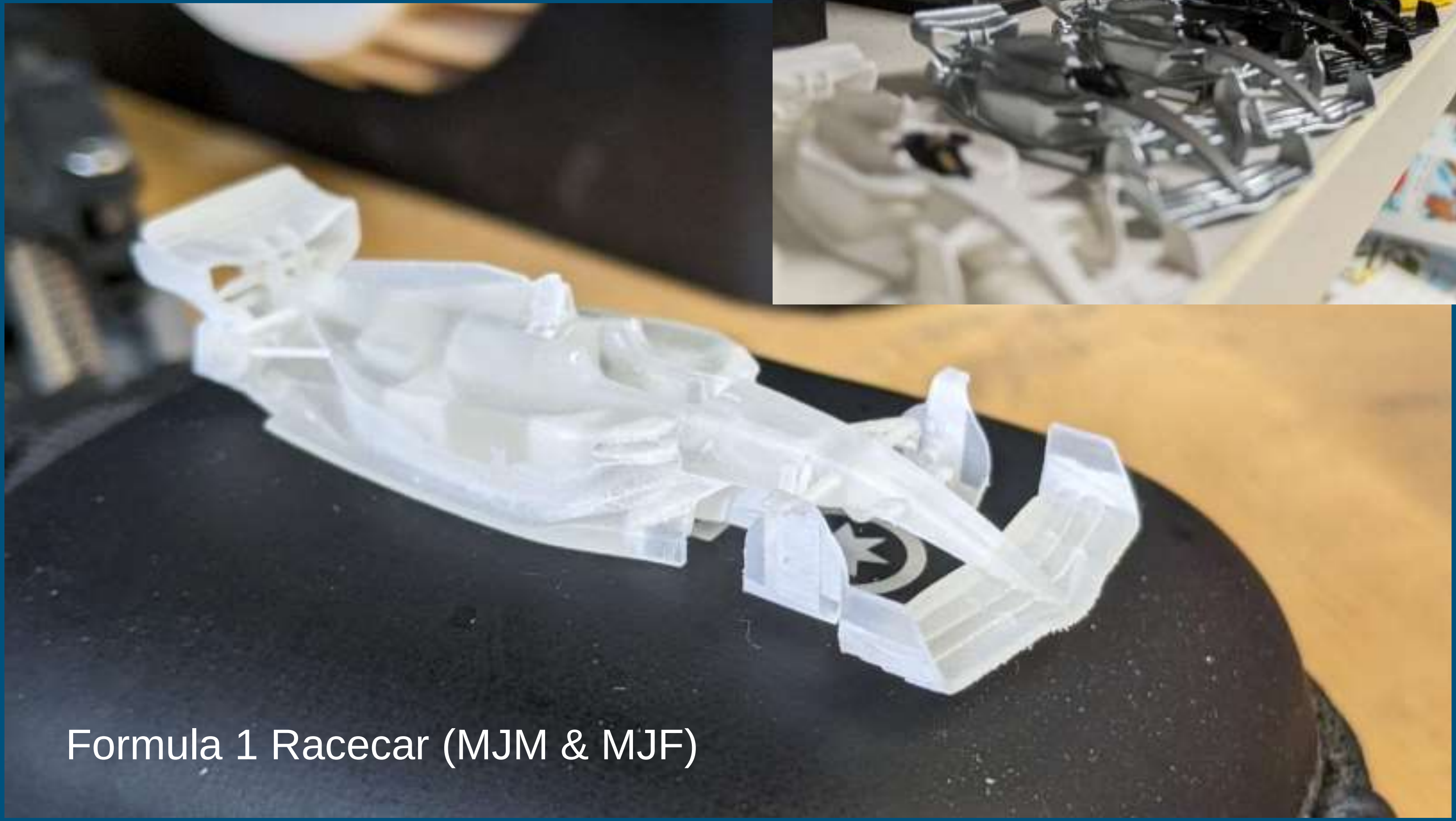
Fun Fair 2020

Internal exhibition: „Sauwohl“ (MJM)

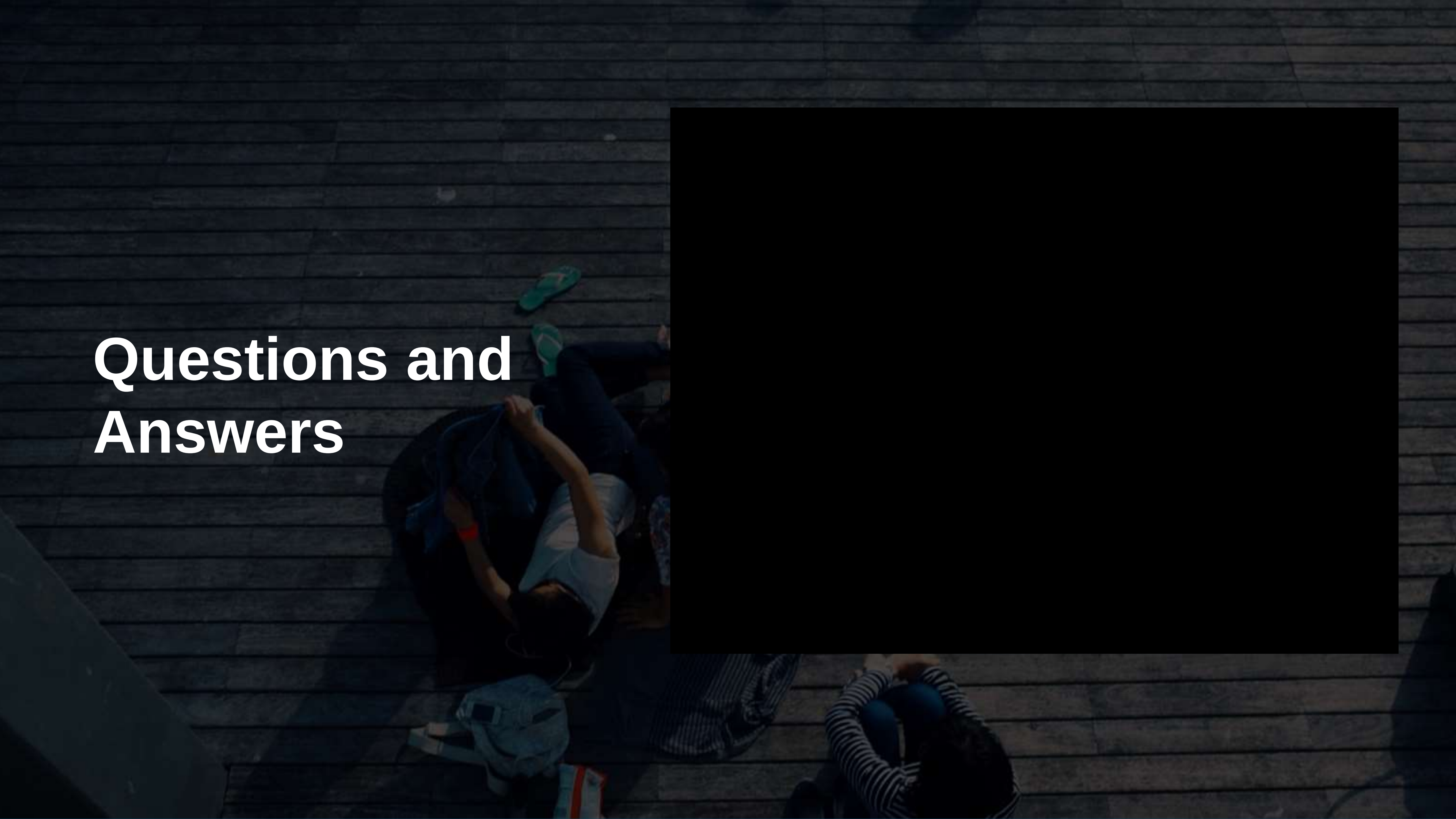
Outbound for suppliers:

Polar bears (ScanLED) - Greta (Vollfarbdruck)

Miniatur concert: Helene Fischer
Farbenspiel (SLS & MJM)



Formula 1 Racecar (MJM & MJF)



Questions and Answers

Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

Additive Alliance® Event

Sustainability Study: AM vs. Traditional Manufacturing

Hamburg, 26.10.2022

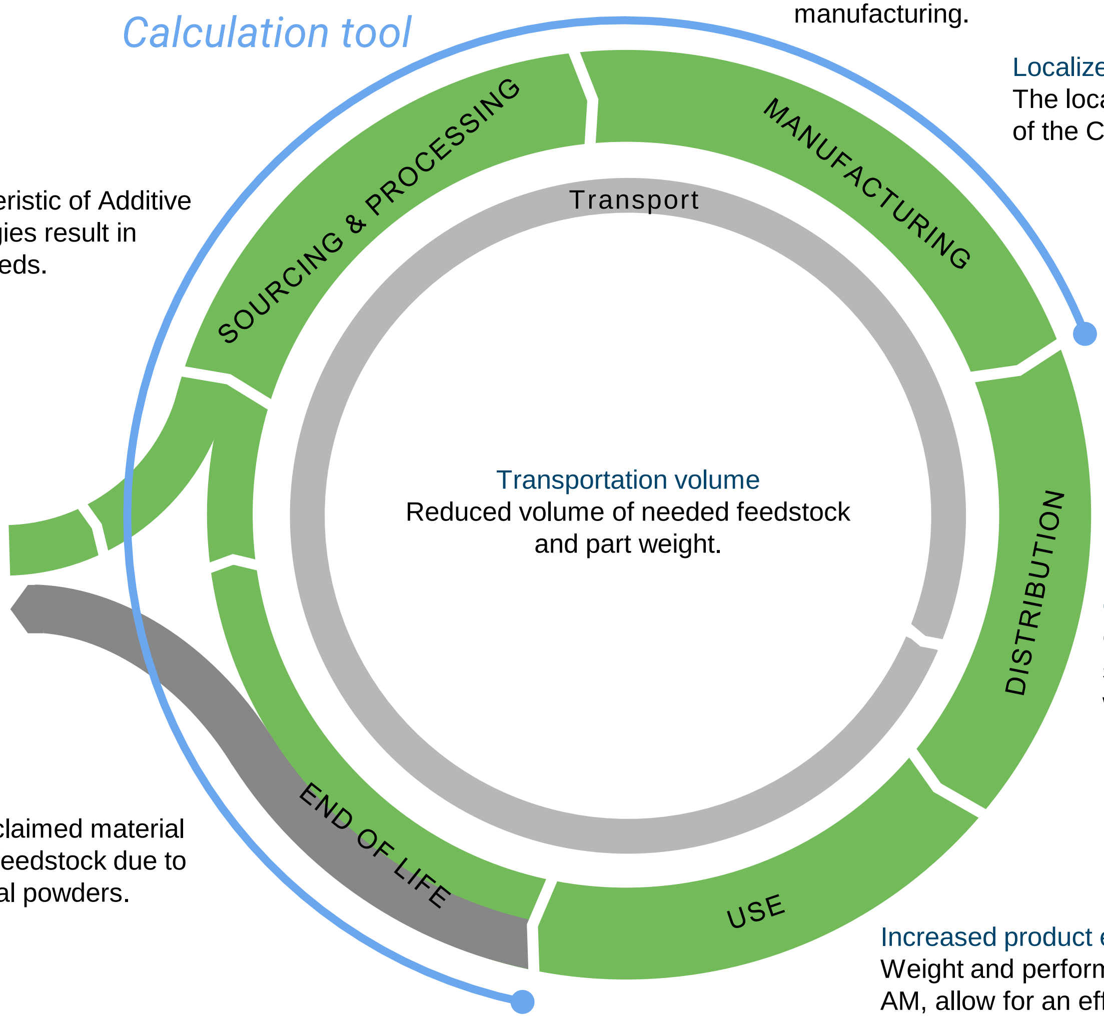
Sustainability potential of Additive Manufacturing in product life cycle

Machining volume
Reduced need for machining due to near-net-shape manufacturing.

Localized manufacturing
The local energy mix is one of the major drivers of the CO_2 footprint.

Manufacturing route
Integrated AM designs reduce manufacturing, transport and assembly efforts and potentially the overall part weight.

Material need
Near-net-shape characteristic of Additive Manufacturing technologies result in reduced raw material needs.



Raw materials & ressource extraction

Landfill & energy recovery

On demand manufacturing
On demand manufacturing will reduce the need for storage capacities and transportation from large warehouses or manufacturing centers.

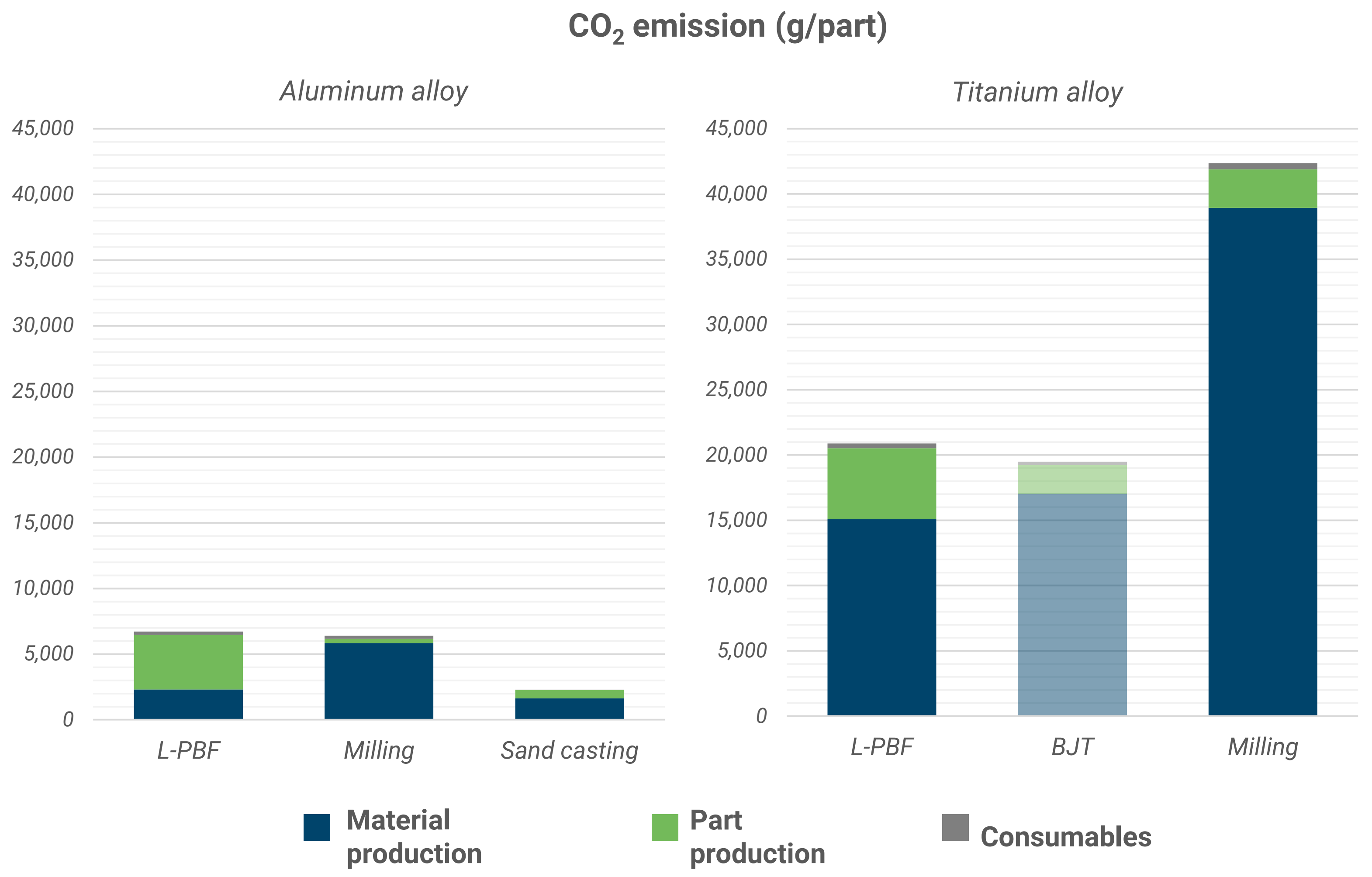
Material recycling
Higher percentage of reclaimed material in the production of AM feedstock due to novel processes for metal powders.

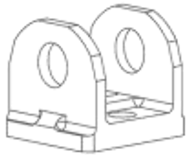
Increased product efficiency
Weight and performance optimized designs, unique to AM, allow for an efficiency increase of e.g. turbines, hydraulics, aircrafts or automobiles.

Quantity	fully utilized
Layer height (PBF / BJT)	60 / 50 µm
Laser power	400 W
Heat treatment	yes
gCO_2/kWh (all processes)	230 (EU Ø)

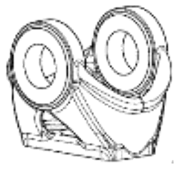
Influence of part design

Topology optimization with 50% weight reduction





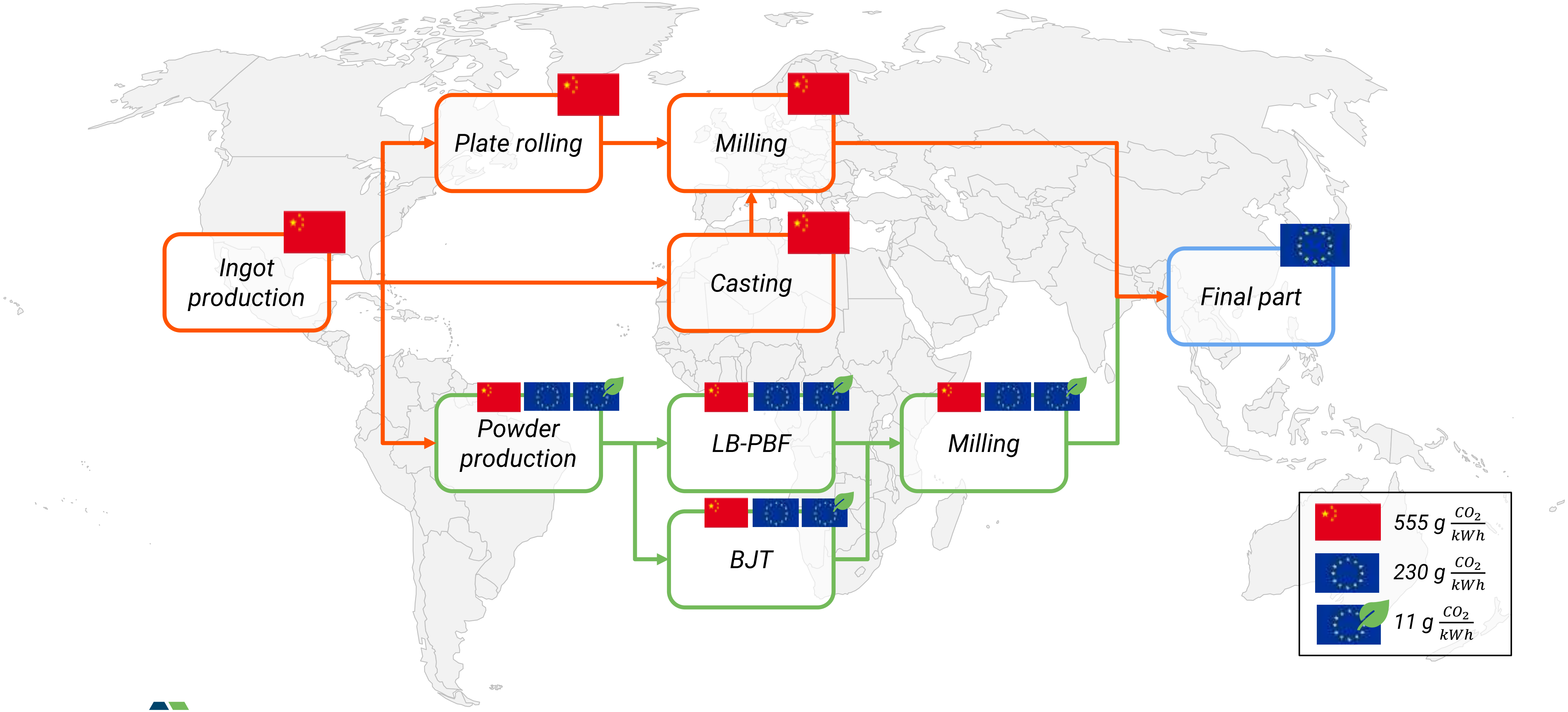
Part design for milling and Wire Arc process



Optimized L-PBF, BJT and casting design with 50 % weight saving

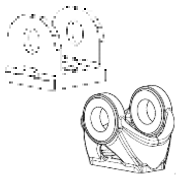
- *Weight optimized part designs result in large reduction of CO_2 footprint*
  - *Reduction in emission nearly linear to weight reduction*
- *Large advantage of near-net shape AM technologies compared to milling for alloys with high embedded energy, e.g. titanium*
  - *Powder production only 10% of the overall material production emission for titanium*

Influence of regional energy mix

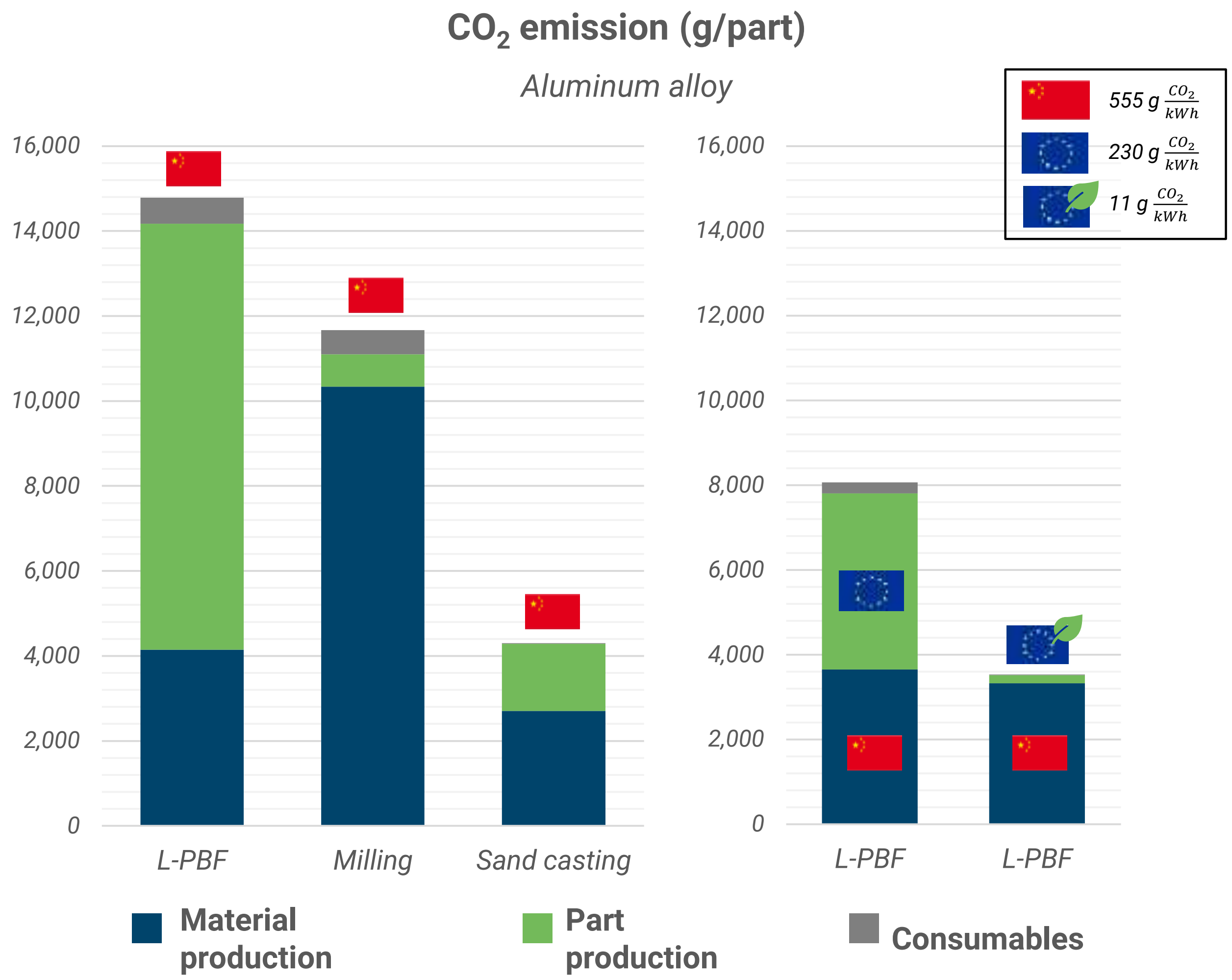


Influence of regional energy mix

Local AM production vs. low-cost sourcing



Quantity	fully utilized
Layer height (PBF / BJT)	60 / 50 µm
Laser power	400 W
Heat treatment	yes
gCO_2/kWh	individual



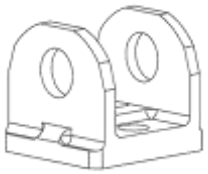
- *Local AM production reduces CO_2 footprint of below sourced milling components*
- *Using „zero-emission" energy mix reduces CO_2 footprint of AM even below sourced castings*
- *Additional CO_2 emission* due to transport of excess material for powder production in Europe is depending on shipment method*
  - *Sea freight: 100 gCO_2 / part*
  - *Air freight: 2.000 gCO2 / part*
- *Considering European ingot production, CO_2 emission will reduce even further to a min. of 1.373 gCO_2 / part*

* CO_2 emission	Air freight	Sea freight
Distance [km]	10.000	25.000
gCO_2 [kg*km]	1	0,02

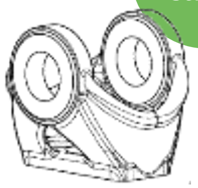
AMPOWER

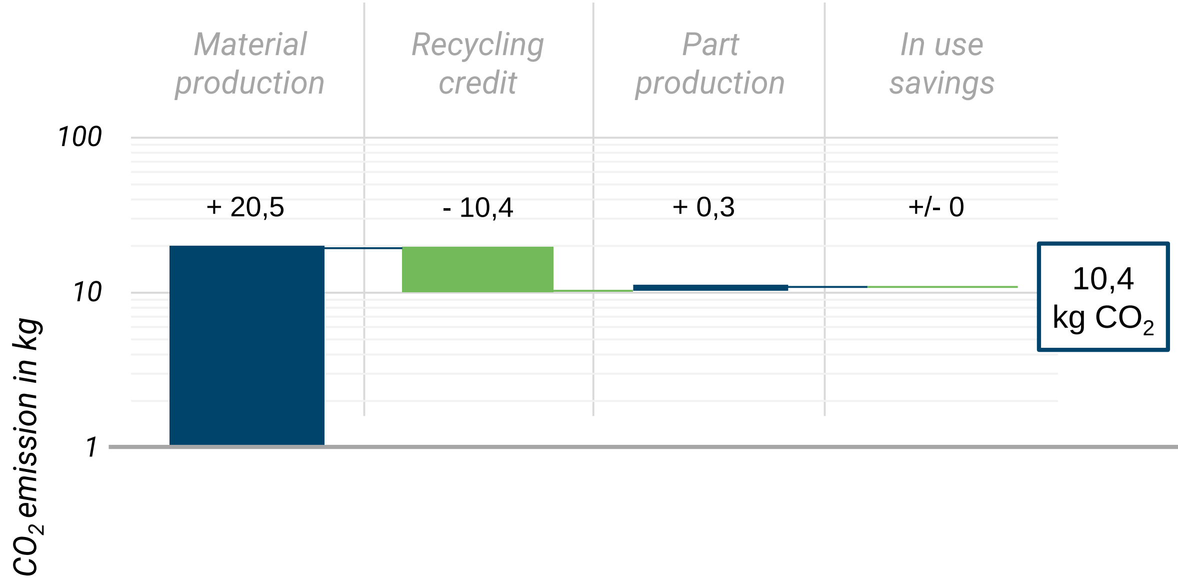
Quantity	fully utilized
Layer height (PBF / BJT)	60 / 50 µm
Laser power	400 W
Heat treatment	yes
gCO_2/kWh	China / EU Ø

In-use savings outweigh production emission substantially



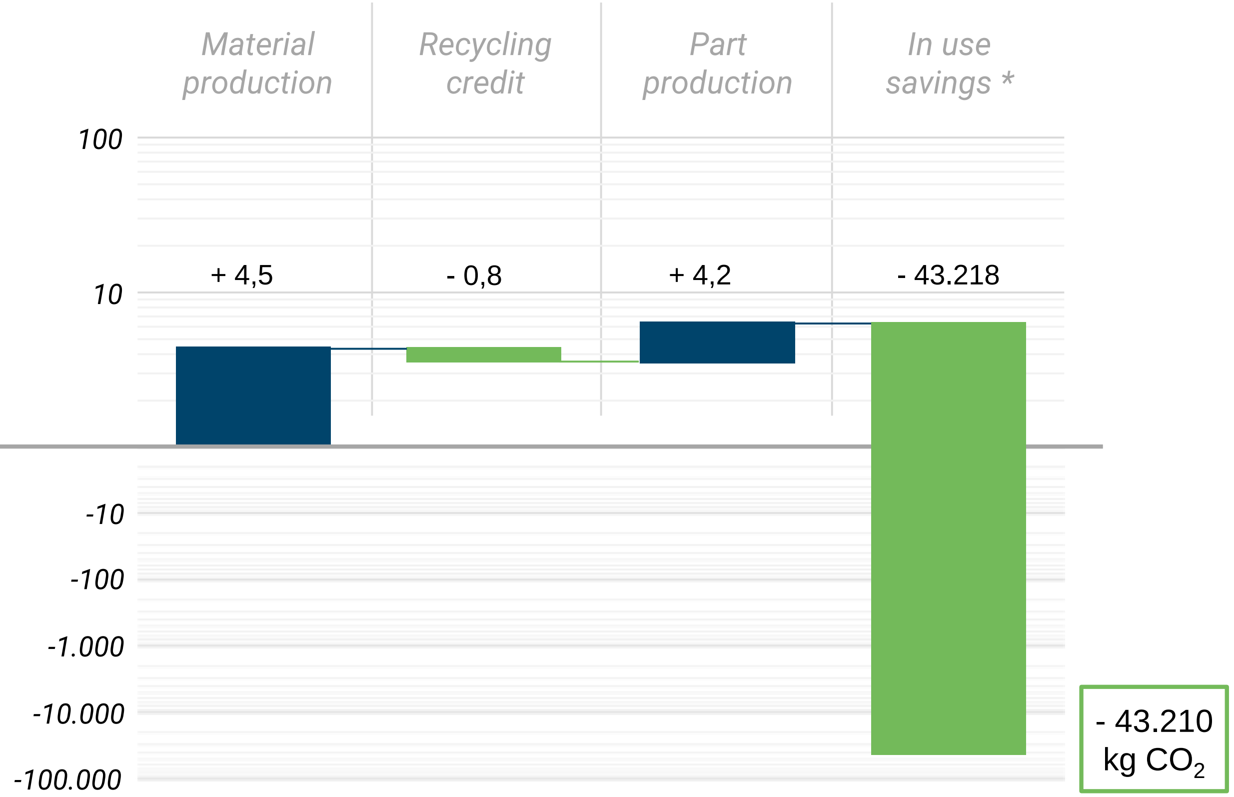
Lifetime CO_2 emission of conventional aluminium aerospace bracket





43 t CO_2 saved

Lifetime CO_2 emission of topology optimized aluminium L-PBF aerospace bracket



** annually 2.500 liter kerosine saved per kg weight saved, assuming a 20 year aircraft lifetime*

AMPOWER

Sustainability of Additive Manufacturing

1 *AM technologies are not self-evidently the most sustainable manufacturing solution. Utilized conventional near net-shape technologies will most likely exhibit a similar or smaller CO_2 footprint.*

2 *Weight optimized AM part designs strongly reduce the CO_2 emission compared to conventional part designs, due to high amount of embedded CO_2 in the raw material and reduced energy need in production.*

3 *In-use savings of weight or efficiency optimized AM designs can be multitudes larger than the emission from part production itself. However, in-use savings are strongly depending on the application.*

4 *For aluminum and steel alloys the regional energy mix of the part production site has a large influence on the overall CO_2 footprint. This favors local AM production powered by renewable energy sources.*

5 *Use of renewable energy in the raw material production process has the biggest influence on the overall CO_2 footprint, especially for titanium alloys.*

6 *Increased recycling rates and new powder production technologies from 100% recycled material will have a significant impact in reducing the CO_2 footprint.*

Source: AMPOWER

AMPOWER

AMPOWER

Empowering your AM business.

Thank you for your attention!

Eric Wycisk
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Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1

DAY 2

public

Vertraulich

Fraunhofer
IAPT

Miele

3D4U

How does 3D4U realize profitability and sustainability?

Powered by Miele

Miele

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Agenda

1 What is 3D4U?

2 Sustainability at 3D4U

3 AM future

4 Time for questions

What is 3D4U?

- **Main mantra: Know-how meets 3D printing**
- Miele is the world's first home appliance manufacturer to offer a major line of 3D-printable accessories
- With 3D4U…
  - … Customers with 3D-printers (FLM) become their own producers of household appliance accessories
  - ... Customers without 3D-printer get desired accessories, which otherwise would not be available
  - … Miele can significantly differentiate itself from competitors

What is our vision?

- 3D4U is another step towards realizing Miele's corporate vision of becoming the most sustainable company in the industry
- One of our goals is also to be able to offer 3D printed spare parts
- For all ideas, Miele is driving the development of components, materials research, as well as testing together with partners

From left to right: Motif dispenser, micro handle, bubble attachment, coffee clips, borehole cleaning aid, valuables separator, twin adapter, mono holder, flexi nozzle.

Digitalization is an enabler for sustainability!

Dr. Markus Miele,

Bits & Pretzels 2022

Sustainability at **3D4U**

Sustainability at **3D4U** - In terms of **ecological responsibility**

- Free print templates + Sales Items
  - Most efficient design - Regarding printed material and printing time (H_2O, CO_2)
  - Support material free printing - directly finished, i.e. without post-processing
  - Designed for single plastic materials
    - Single type recycling at the local recycling center

- Free print templates
  - No packaging and no transport

Sustainability at 3D4U – In terms of **social responsibility**

- Delight the customer
- Free print templates & Sales Item
  - Existing filament materials can be used
    - No need to purchase new material
  - In case new material is needed
    - Buy filament on recycled cardboard coils

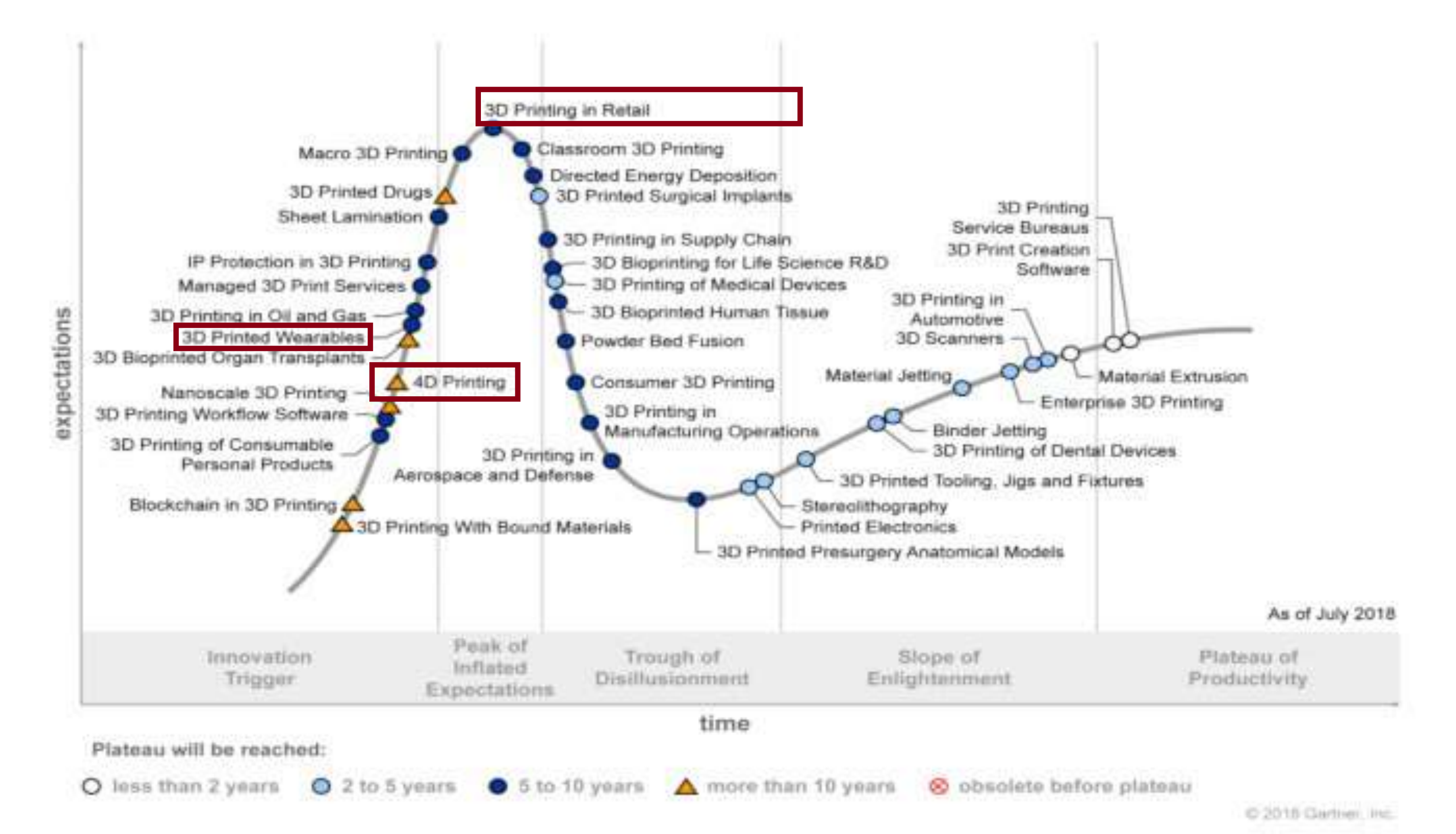
- Free print templates
    - Customer = manufacturer
      - Participation in component development possible
      - Better printing results with fewer iteration loops

Sustainability at 3D4U - In terms of **economic responsibility**

- Free print templates + Sales Item
  - Long life
  - Compatible with the best-selling products for the widest possible range of applications
  - Significant differentiation from competitors
- Free print templates
  - Radical break with classic B2C
    - Miele customers receive a purely digital product rather than a physical one

AM - future

Gartner Hype Cycle 2019: 3D Printing Predictions - 3Dnatives



Miele

Success or failure –
both are always better in a team!

Feel free to cooperate with us - What helps you can also help us!

Miele maintains an exchange with all stakeholders at the e-mail address 3D4U@miele.com

We can also get in touch directly at alexander.schoenfeld@miele.com

Time for questions

Miele

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Alliance Event October

Please click on one of the slides to go directly to the corresponding topic.

DAY 1 **DAY 2**

Optimization and design for additive manufacturing of a fuel cell end plate

Dirk Herzog[1], Tim Röver[1], Sagynsysh Abdolov[1], Florian Becker[2], Christoph Gentner[2]

iLAS Institute of Laser and System Technologies
Prof. Dr.-Ing. C. Emmelmann
Hamburg University of Technology
TUHH Hamburg University of Technology 1)

DLR Institute of Engineering Thermodynamics 2)

Outline

1 Introduction

2 Methodology

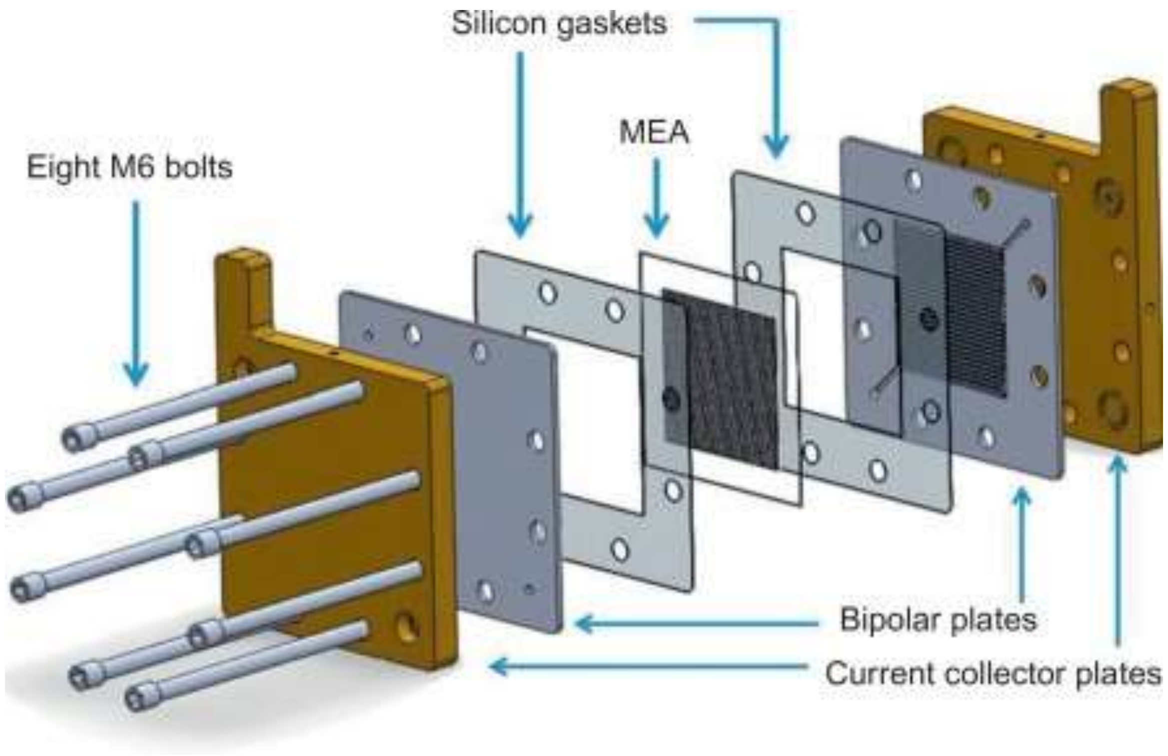
3 Design Study

4 Manufacturing and Validation

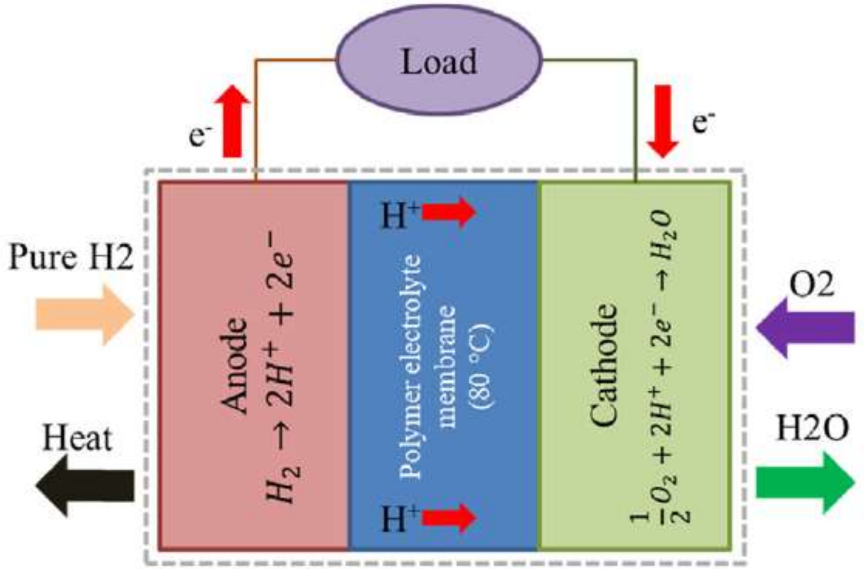
5 Conclusions & Outlook

Introduction

- Proton Exchange Membrane Fuel Cell (PEMFC)



Barbir et al., Compendium of Hydrogen Energy, 2016, ISBN 978-1-78242-363-8



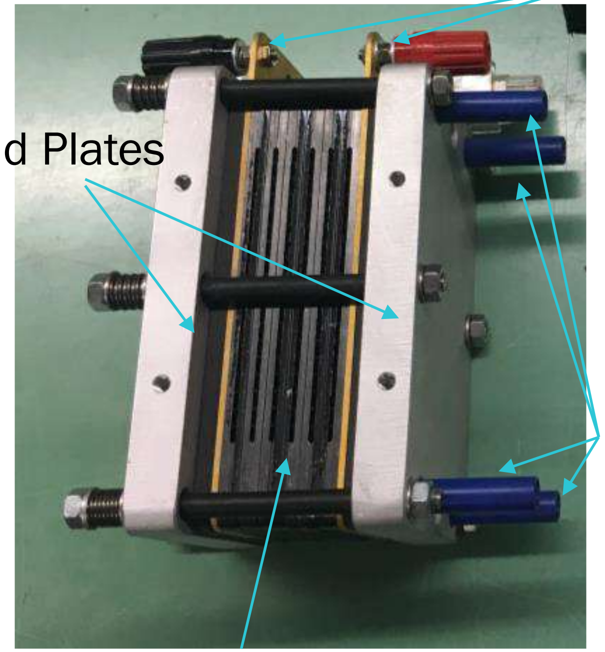
Baroutaji et al., Renewable and Sustainable Energy Rev 106 (2019) 31-40

- Common type of fuel cell due to
  - high power density up to 2 kW/kg
  - low operating temperature of ~ 80 °C
  - comparatively low costs of 280 US$/kW

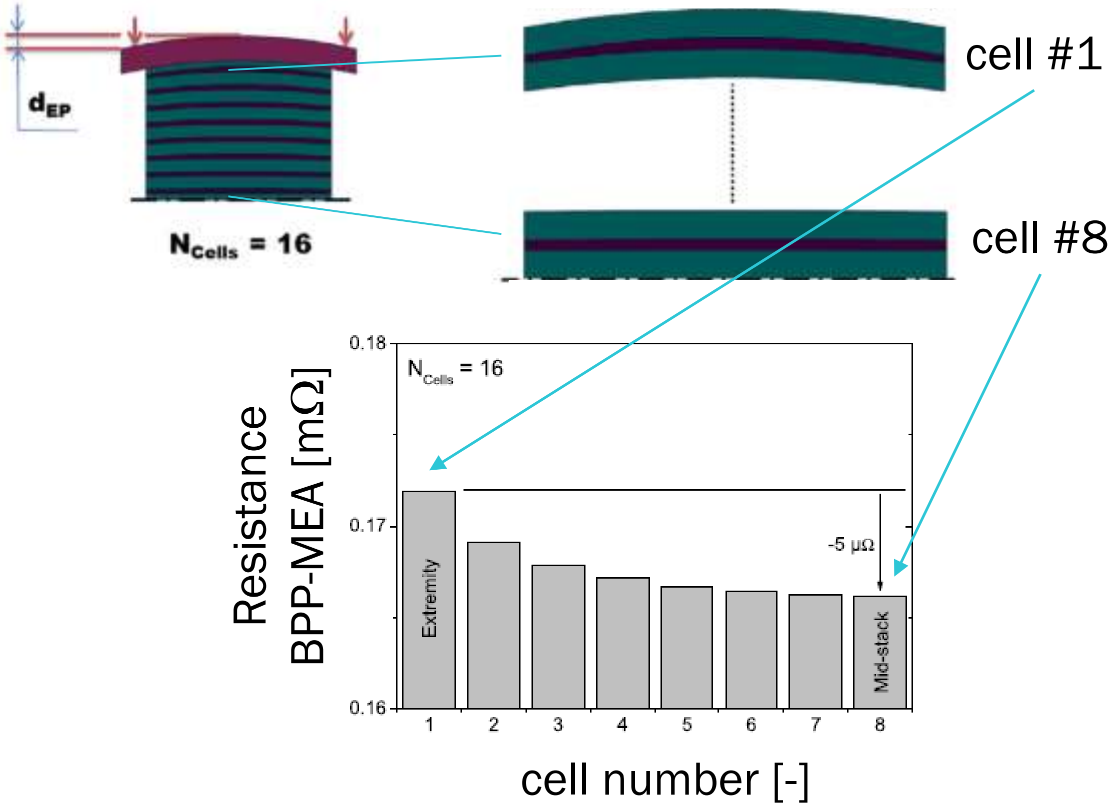
Institute of Engineering Thermodynamics

Introduction

Assembly of PEMFC



Function of the end plate



C. Carral and P. Méle, Inter J of Hydrogen Energy 39 (2014) 4516-4530

Outline

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Methodology

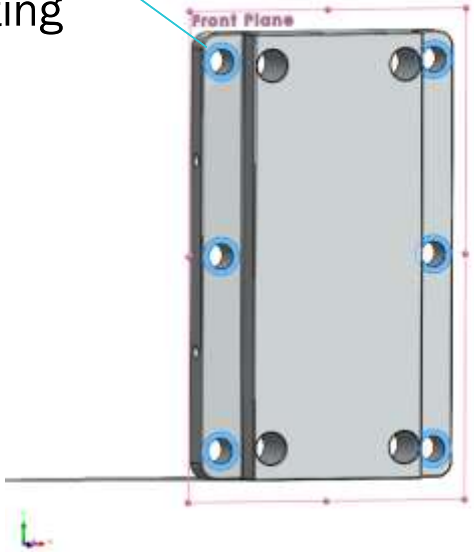
- optimization goals
  - mass reduction
  - homogenous pressure distribution

- material selection
- design space generation
- mechanical boundary conditions
- Topology Optimization (TO)

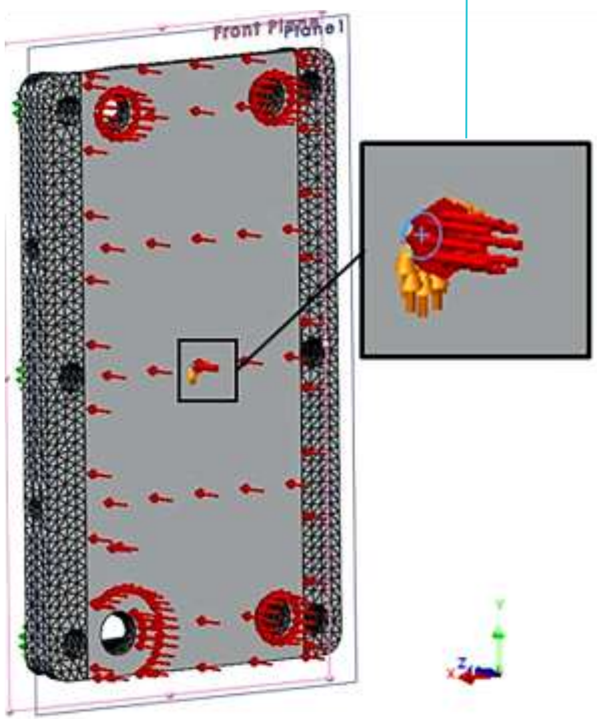
↓

- Resulting structure subjected to loading
- FEA ⟶ evaluation of displacement on active area
- measure for pressure distribution

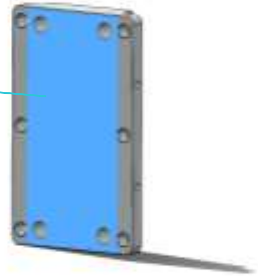
loads applied from bolting



fixing in remaining degrees of freedom to obtain well-defined mechanical problem



constant pressure applied to active area



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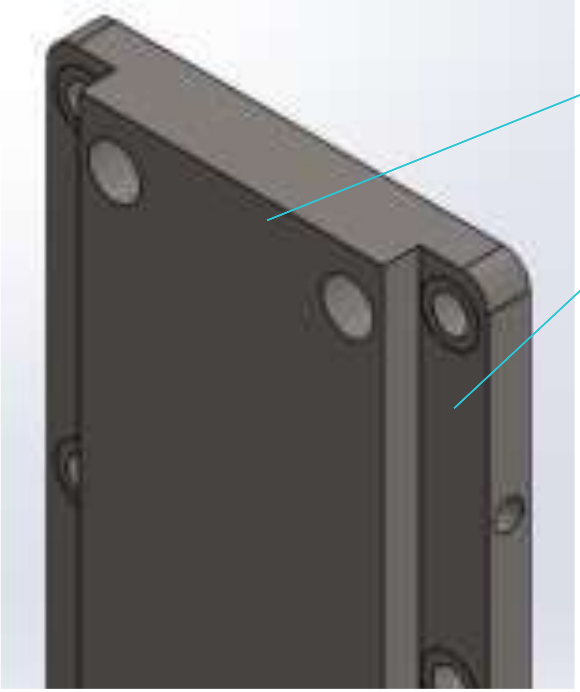
Preliminary Design Study

Original end plate
140 x 84 x 15mm³

AA1060, m = 435g

Δz_{AA} = 1.38x10^{-3}mm

TO Design Space



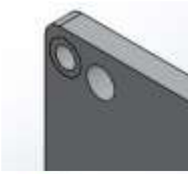
extrusion z_{ex},
varied = 0…30 mm

base thickness z_{base},

- AlSi10Mg = 10 mm
- Ti6Al4V = 8 mm

TI6Al4V, z_{base} = 8 mm

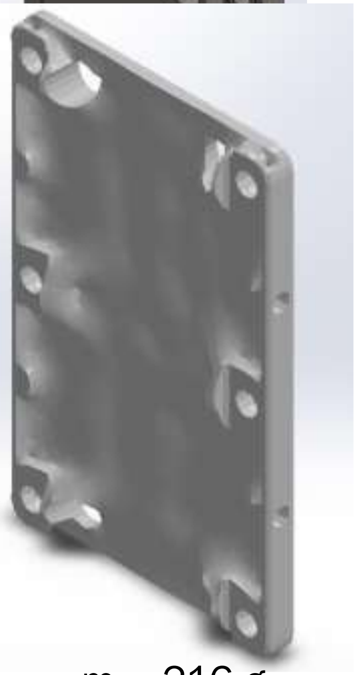
z_{ex} =0 mm



m = 204 g

Δz_{AA} = 1.72x10^{-2}mm

z_{ex} =7 mm



m = 216 g

Δz_{AA} = 1.64x10^{-2}mm

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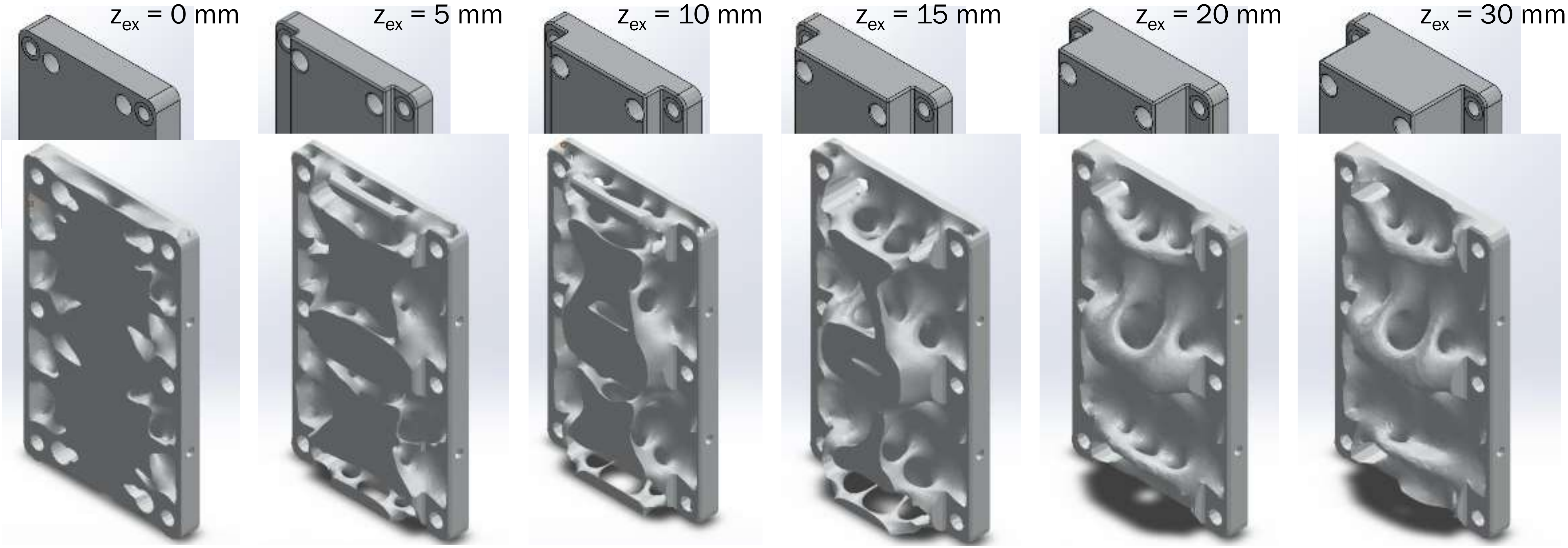
Preliminary Design Study

AlSi10Mg, z_{base} = 10 mm

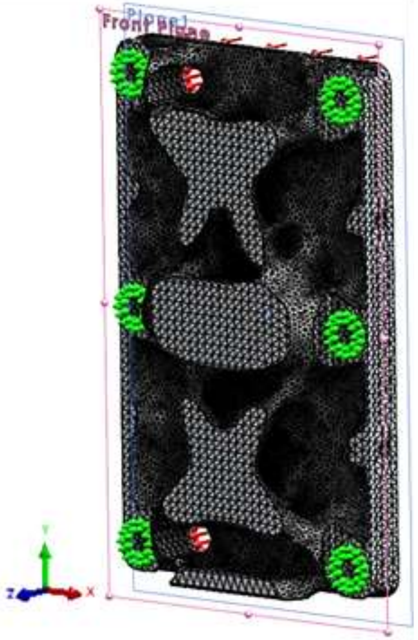


m = 240 g	m = 238 g	m = 232 g	m = 234 g	m = 242 g	m = 240 g
Δz_{AA} = 4.03x10^{-3}mm	Δz_{AA} = 3.00x10^{-3}mm	Δz_{AA} = 2.91x10^{-3}mm	Δz_{AA} = 3.46x10^{-3}mm	Δz_{AA} = 3.76x10^{-3}mm	Δz_{AA} = 4.07x10^{-3}mm

Final Design Study

based on pre-selected design:

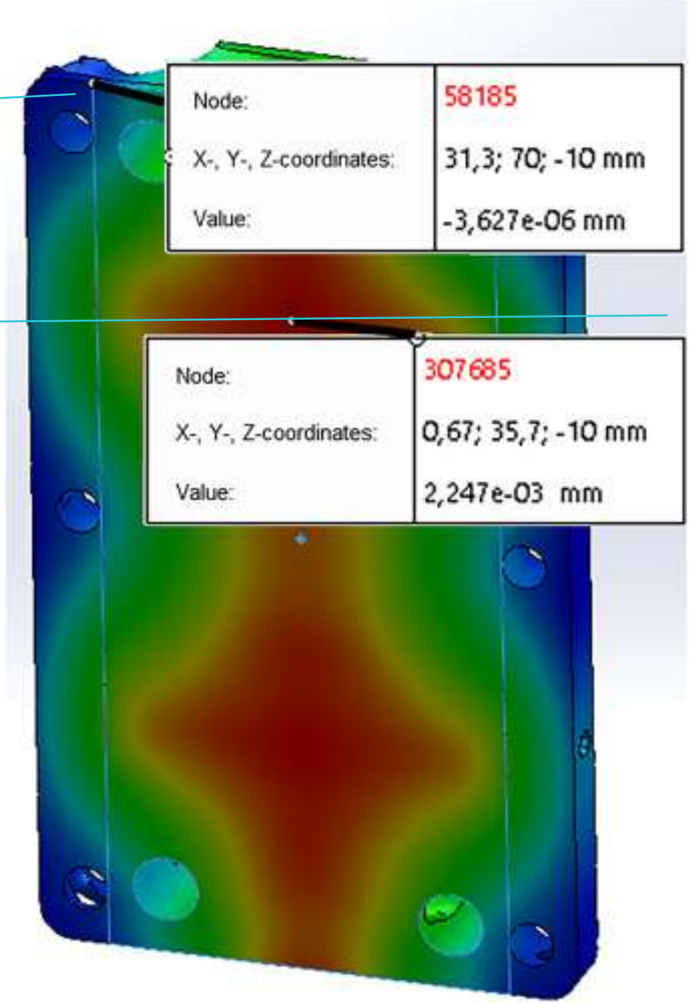
- AlSi10Mg, z_{base} = 10 mm
- extrusion thickness z_{ex} = 10 mm



study	mesh size	$\sigma_{von\ Mises,\ max}$	Δz_{AA}	mass
preliminary	2.5 mm	37.5 MPa	2.91×10^{-3} mm	232 g
final	1.5 mm	34.5 MPa	2.25×10^{-3} mm	226 g

FEA minimum displacement

FEA maximum displacement



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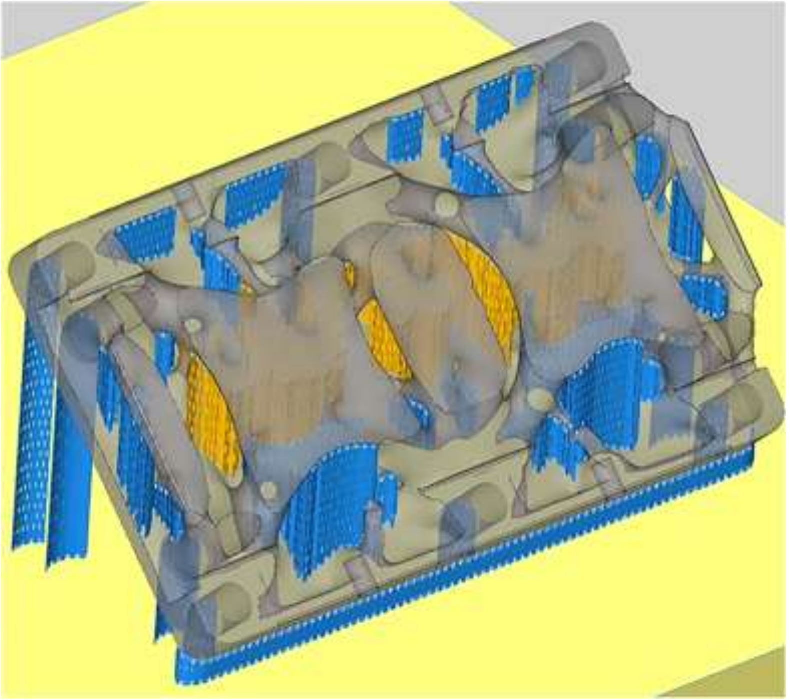
Outline

DLR Institute of Engineering Thermodynamics

iLAS TUHH Hamburg University of Technology

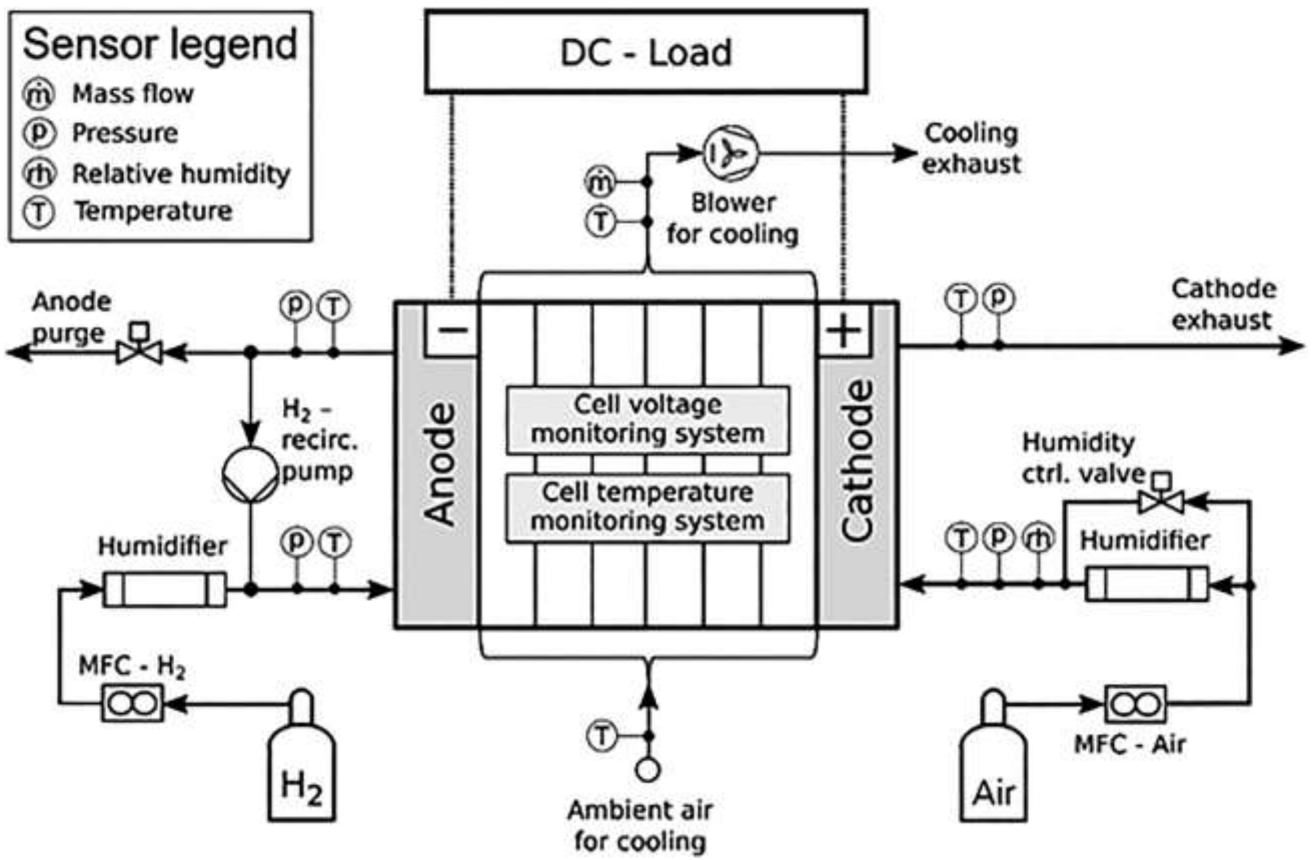
Manufacturing and Validation

- L-PBF of optimized end plates
- all elements > 0.5 mm wall thickness
- 1.5 mm additional material at the bottom area, milling to final surface of active area to remove any warpage



Manufacturing and Validation

Experimental set-up used for validation



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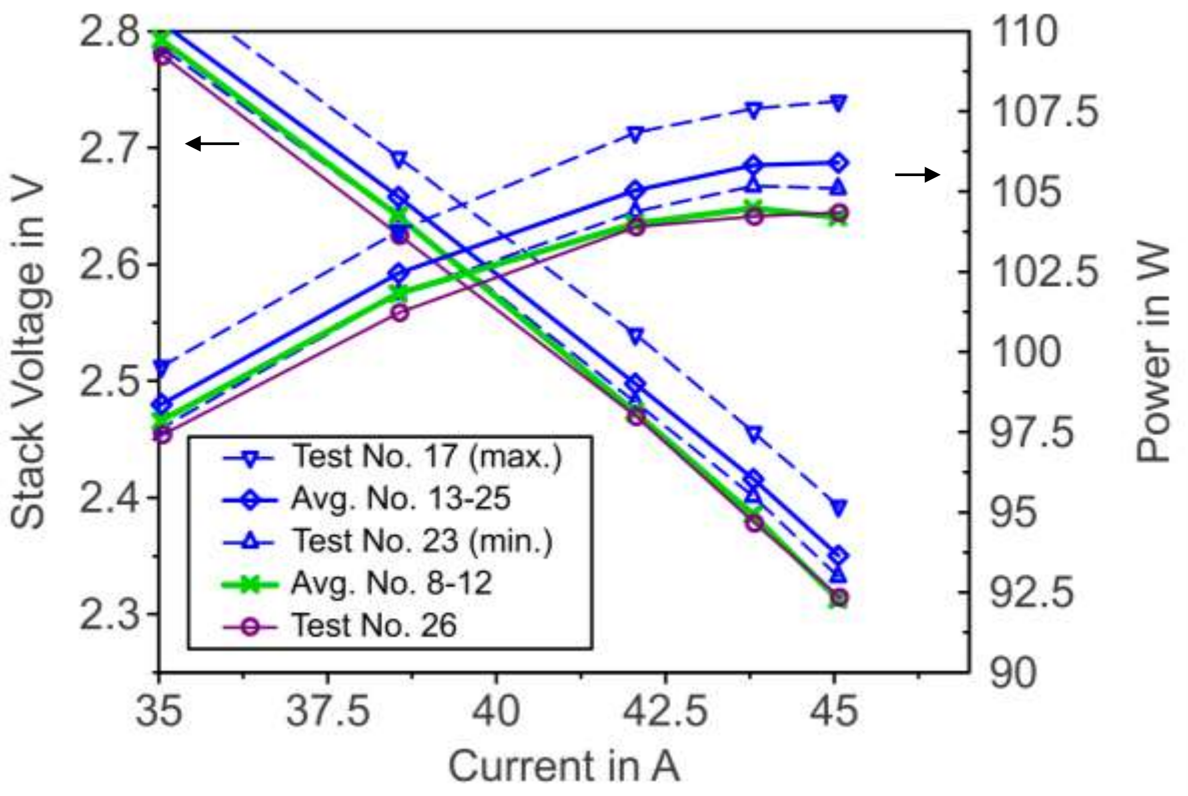
Manufacturing and Validation

validation procedure:

- conditioning w original plates (#1-7)
- measurement w original plates (#8-12)
- measurement w optimized plates (#13-25)
- re-mounted original plates (#26)

- performance of PEMFC @ 45 A:
- conventional plates: P_{avg} = 104.8 W
- optimized plates: P_{avg} = 105.9 W



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Conclusions and Outlook

- PEMFC end plates have been optimized for mass and homogenous pressure distribution
- AlSi10Mg using TO with a boundary box of 10 mm base puls 10 mm extrusion
- Mass saving of approx. 48%
- Experimental evaluation in PEMFC set-up proved an additional performance increase by approx. 1 %

- Investigate larger extrusion with smaller mesh size to understand limitations
- Re-design for better manufacturability
- Transfer to other PEMFCs (e.g. more bolts)

Acknowlegdments

The authors would like to express their gratitude to the company Franken Guss GmbH & Co. KG for the support and discussion of the printing of the end plates. Furthermore, the authors would like to thank Anna Vorndran (DLR) for carrying out the experimental campaign.

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iLAS
TUHH Hamburg University of Technology

Thank you!

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Institute of Laser and System Technologies (iLAS)
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21079 Hamburg

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E-Mail: dirk.herzog@tuhh.de