

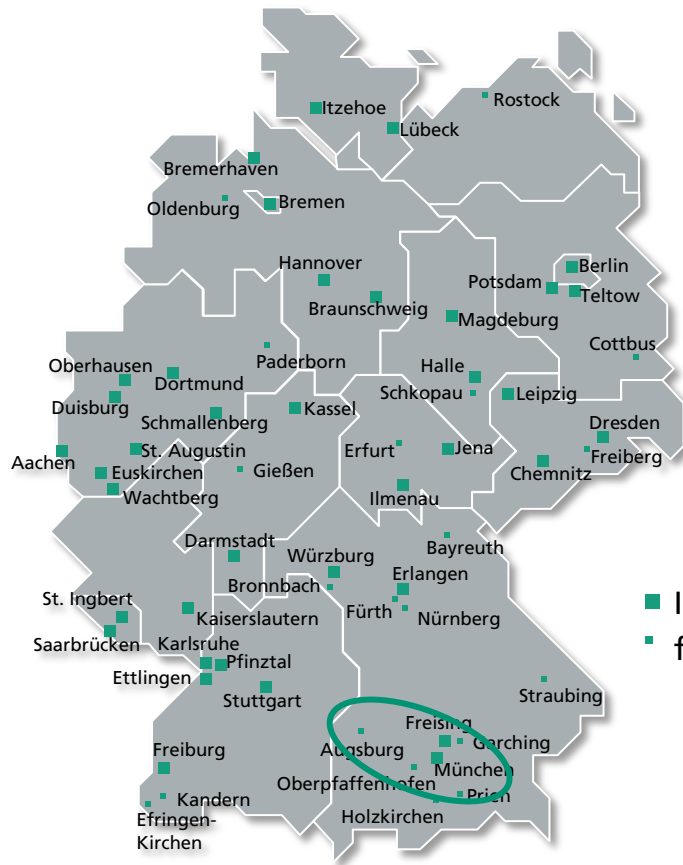
PROJEKTGRUPPE

RESSOURCENEFFIZIENTE MECHATRONISCHE VERARBEITUNGSMASCHINEN

BIOTRIZ – PROCESS KNOW-HOW, DESIGN METHODOLOGIES AND SOFTWARE TOOLS FOR ENHANCED ADDITIVE MANUFACTURING

GEOGRAPHICAL ORIENTATION

RESEARCH ON RESOURCE-EFFICIENT MACHINES AND COMPONENTS



- Fraunhofer-Organization
 - Largest application-oriented research organization in Europe
 - Over 80 research institutions in Germany
 - International institutions
 - > 23 000 employees
 - 2 Billion € annual research volume
- Institutes and institutions
- further locations



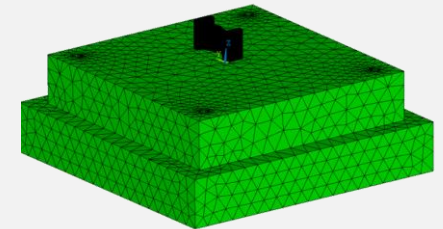
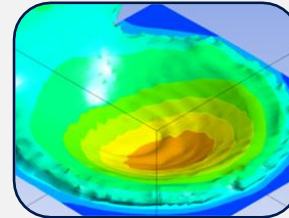
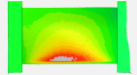
AMLAB – JOINT LABORATORY OF FRAUNHOFER IWU AUGSBURG AND TU MUNICH

RESEARCH AREAS

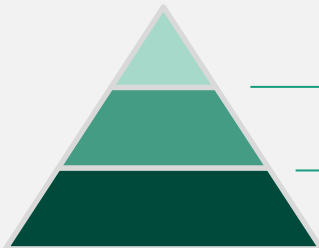
Process Development and Monitoring



Simulation



Industrial Application

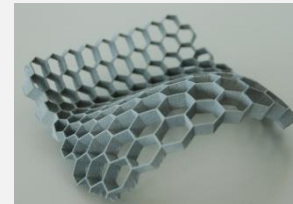


Product

Add value

Organization

Design for Additive



AMLAB – JOINT LABORATORY OF FRAUNHOFER IWU AUGSBURG AND TU MUNICH

EQUIPMENT

Laserstrahlschmelzen

Concept Laser



Laserstrahlschmelzen Laserstrahlschmelzen

EOS



SLM Solutions



Lasersintern

EOS



Rauheitsmessung

Mitutoyo



Elektronenstrahlschmelzen

Eigenentwicklung



Mechanische Prüfung
Zug, Härte (Zwick Roell)



3-D-Druck
Voxeljet



Fused Deposition Modelling
Stratasys



Digitalisierung
Steinbichler



Laserscan-Mikroskopie
Keyence



Metallographielabor
ATM

AGENDA

- 1 Process know-how
- 2 Design methodologies
- 3 Software tools

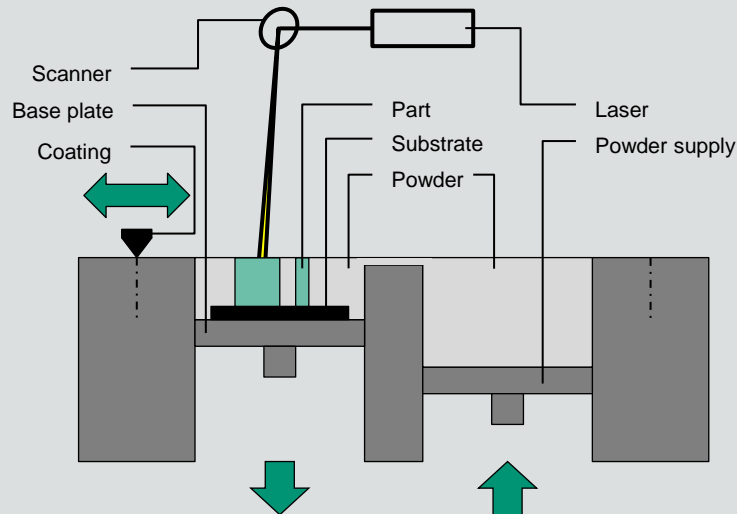


PROCESS KNOW-HOW

LASER BEAM MELTING

Functional principle

Powder-bed based manufacture via local selective melting of material



Laser Beam Melting

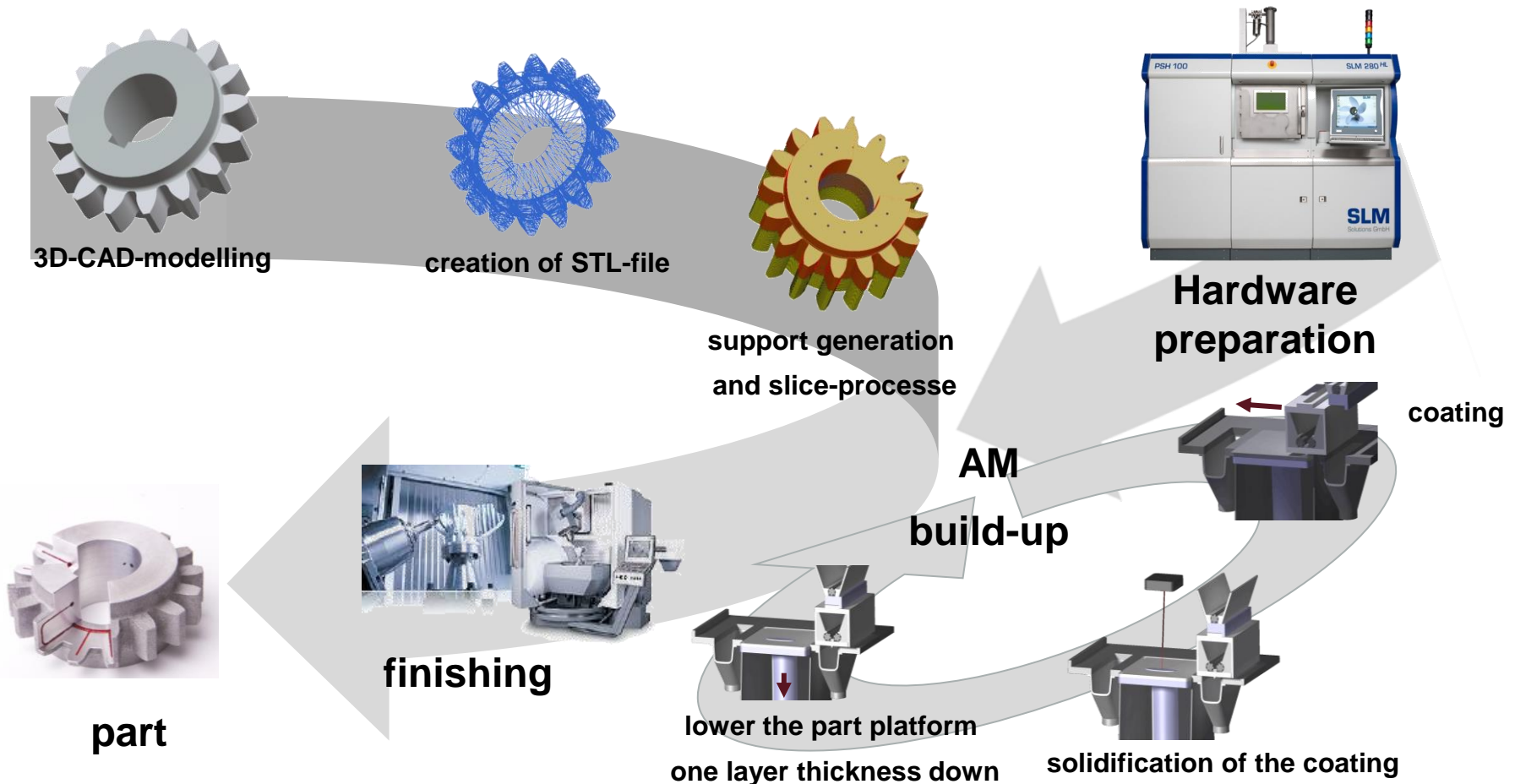
- Manufacturing costs almost independent from complexity
- Design freedom (Multimaterial design etc.) and wide material range
- Material specific constraints



➔ Additive manufacturing offers tremendous design potential, however there are limitations that need to be considered by design methodologies and software

PROCESS KNOW-HOW

ADDITIVE MANUFACTURING PROCESS CHAIN



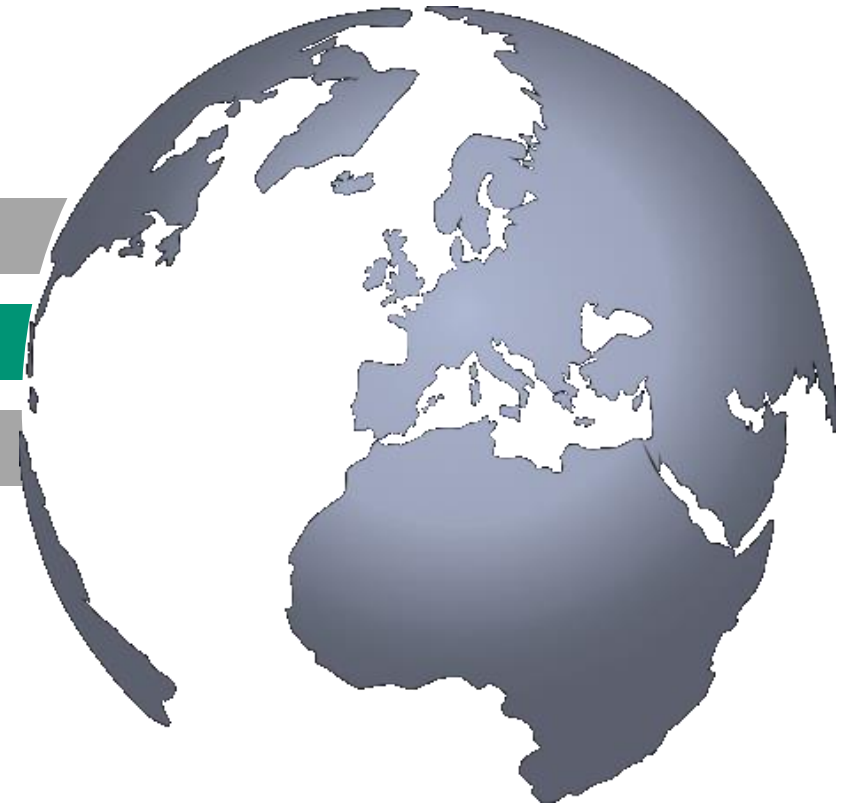
➔ Whole process chain needs to be considered for economic part design

AGENDA

1 Process know-how

2 Design methodologies

3 Software tools



DESIGN METHODOLOGIES

HOW TO OPTIMIZE THE DESIGN PROCESS SPECIFICALLY FOR LASER ADDITIVE MANUFACTURING?

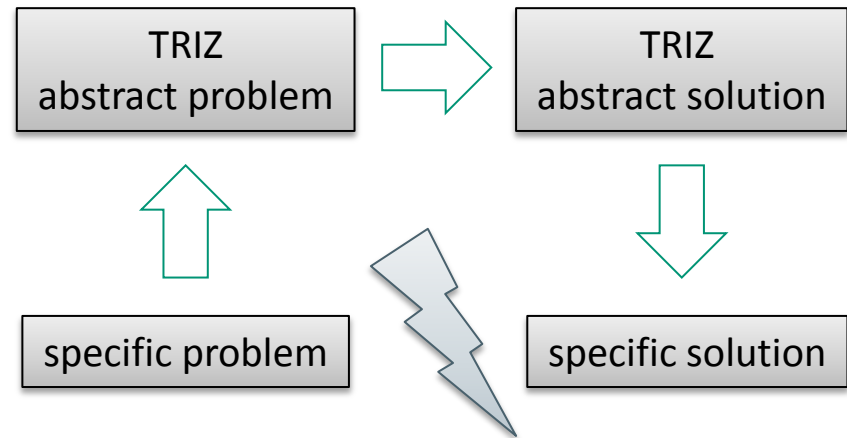
DESIGN FOR AM

VDI 3405: part orientation, application of support structures, material properties, post-processing etc.

“designer’s mind-sets have to adapt to a different way of production and design”

VDI status report of 2014

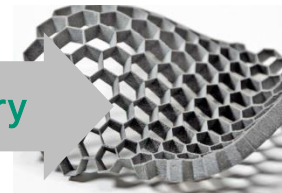
application-oriented methodology



„theory of inventive problem solving“
LINDEMANN 2009, 2014; SCHAAL 2011



biomimicry



„learning from nature“
NACHTIGALL 2002

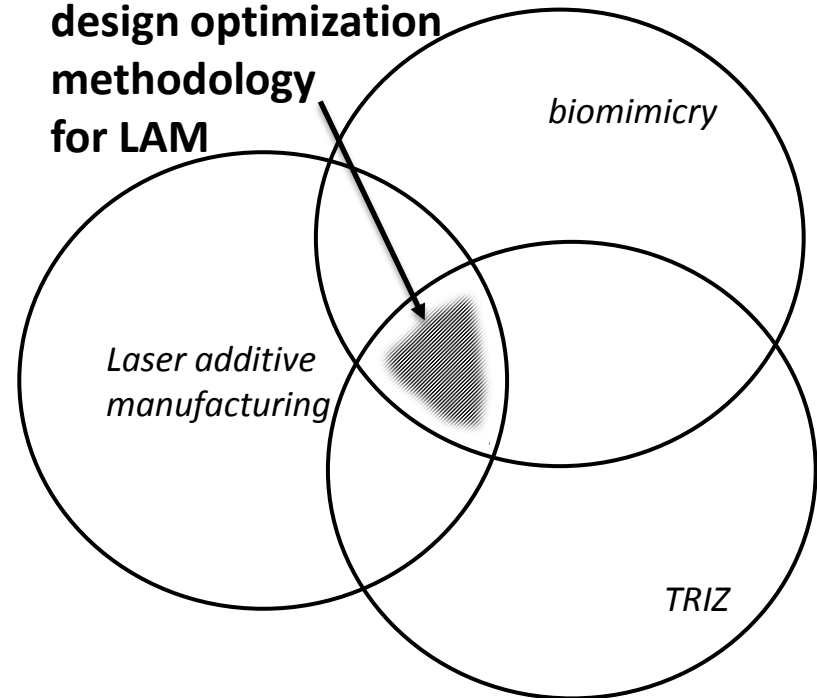
DESIGN METHODOLOGIES

TRIZ-BASED INTEGRATION OF BIOMIMETICS AND DESIGN FOR AM

OBJECTIVES

- PICKING SUITABLE METHODS FROM THE TRIZ-METHODOLOGY
- EFFICIENT OPTIMIZATION OF A GIVEN PART
- SYSTEMATIC CREATION OF LARGE SOLUTION SPACE OF BIOMIMETIC ANALOGIES FOR GIVEN APPLICATION
- EVALUATION OF SUITABLE ANALOGIES
- EVALUATION OF CREATED SOLUTIONS IN TERMS OF DESIGN RESTRICTIONS DICTATED BY LASER ADDITIVE MANUFACTURING
- ENSURING APPLICATION-ORIENTATION WITHOUT REDUCING SOLUTION QUALITY

TRIZ-based application-oriented design optimization methodology for LAM



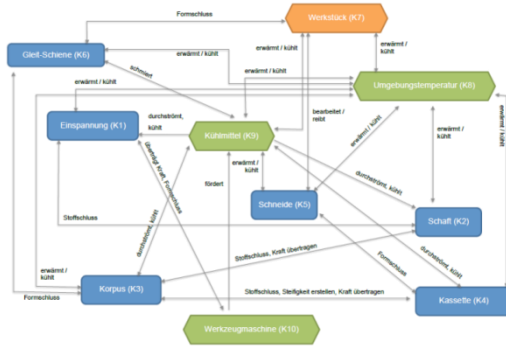
DESIGN METHODOLOGIES

TRIZ-BASED BIOMIMETIC PART DESIGN FOR LAM

2

TRIZ
abstract problem

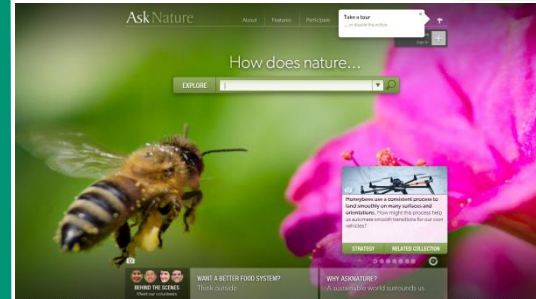
impact analysis
and problem
formulation



3

TRIZ
abstract solution

solution space
generation via
biomimicry



1

augmented
functional modelling
specific problem

$$FI = \frac{1}{e^{\frac{1}{n} \sum_{i=1}^n \left(\frac{|x_{BT,i} - x_{p,i}|}{x_{p,i}} \right)}}$$

analytical
evaluation

4

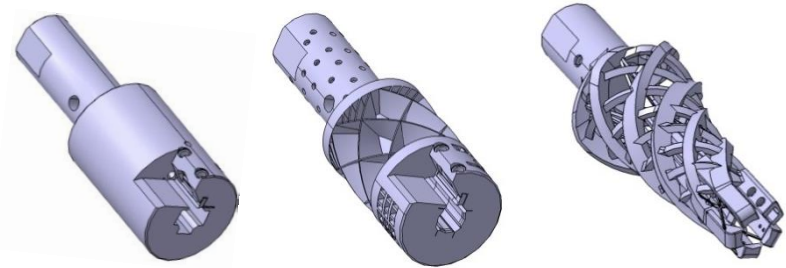
specific solution

application-oriented methodology for functional part optimization

www.asknature.com, Zugriff am 14.06.2015, The Biomimicry Institute

CASE STUDY

EXTERNAL REAMER PROVIDED BY MAPAL DR. KRESS KG – RESULTS AND EVALUATION



	Reamer conventional	Reamer LAM-non-TRIZ-optimized	Reamer TRIZ-optimized
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PART-DATA

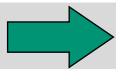
mass (TiAl6V4)	m [g]	232	107	86
volume	$V_{BT} V_{BT}$ [mm ³]	52080	23980	19280
surface	$O_{BT} O_{BT}$ [mm ²]	15000	33000	36000

PROCESS-PERFORMANCE

complexity-index	KI	3,28	6,30	7,11
massivity-index	MI	0,82	0,66	0,56
orientation-index	OI	0,63	0,83	1,25

PART-PERFORMANCE

lightweight construction indicator	LCI (normalized)	0,03	0,09	0,49
mass ratio	MA [%]	100	46	37
safety-index	SI	159	131	29



the systematic approach offers better design results regarding process and part performance

DESIGN METHODOLOGIES

...NATURE KNOWS BEST...

- LAM POSSESSES A GREAT POTENTIAL REGARDING PART COMPLEXITY AND ADAPTION FOR AN INNOVATIVE PART DESIGN
- THUS, DESIGN OPTIMIZATION IS A COMPLEX CHALLENGE FOR THE DESIGNER THAT REQUIRES SYSTEMATIC DESIGN APPROACHES FOR OPTIMAL USE OF "COMPLEXITY FOR FREE"
- NATURE OFFERS A VAST SOLUTION SPACE FOR TECHNICAL PROBLEMS
- THE CASE STUDY OF AN EXTERNAL REAMER SHOWS A SUPERIOR SOLUTION TO A TRIAL-AND-ERROR APPROACH

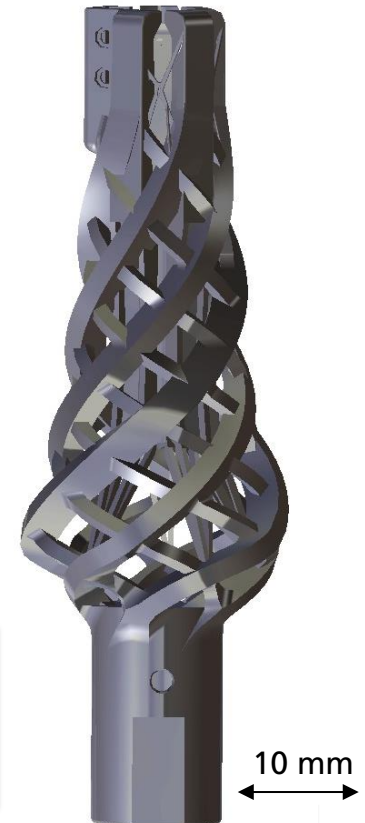
LAM leverages an economical transfer of analogies due to low part complexity costs.

In spite of 250 years of taxonomic classification and over 1.2 million species already cataloged in a central database, 86% of existing species on Earth and 91% of species in the ocean still await description (Mora et al. 2011).

Biological solutions have been field-tested for over 3.8 billion years.



Constantly growing analogy database to be used specifically for LAM!



AGENDA

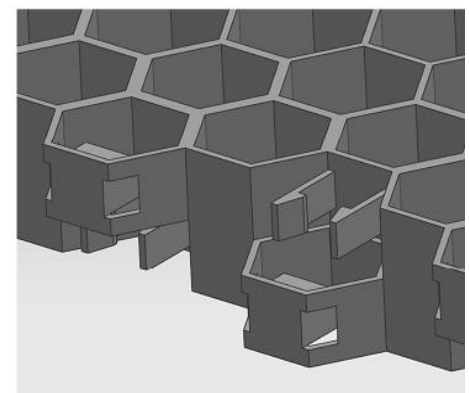
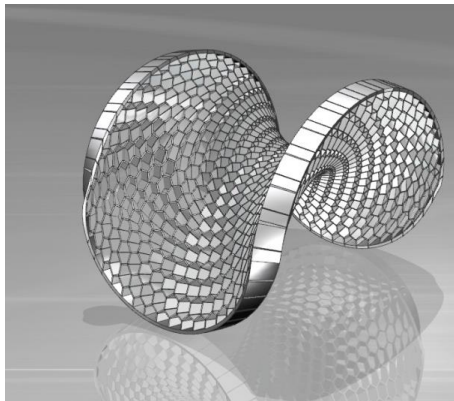
- 1 Process know-how
- 2 Design methodologies
- 3 Software tools



CASE EXAMPLE

HONEYCOMB STRUCTURE

- Honeycomb cores are more resilient than homogeneous cores because of their structure
- Usage as sandwich part is beneficial
- AM advantages:
 - Adaption of honeycomb cores to any free-form surface
 - Functional integration in sandwich parts (e.g. integrated threads or plug connectors)



SOFTWARE TOOLS

LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

4-STEP-PROCEDURE

- ✓ Developed at Fraunhofer IWU*
- ✓ Add-on for Siemens NX 8
- ✓ Graphical User Interface (GUI)
- ✓ Source-Code in C#



*also suitable for lattice structures

Screenshot of Fraunhofer Add-on

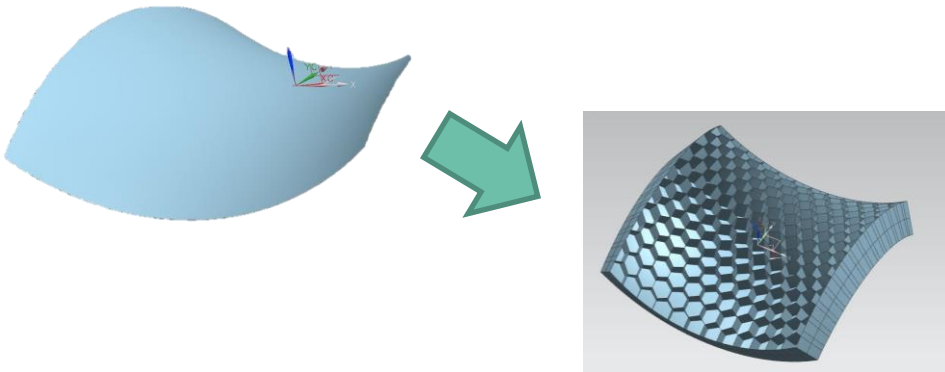
SOFTWARE TOOLS

LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

DESIGNING FREEFORM SURFACE

Design Freeform Surface

1. Designing or selecting a freeform surface
2. Parameter-Input (wall thickness, diameter, conformal, uniform)
3. Calculating and generating the honeycomb along normalvector



Screenshot of Fraunhofer Add-on

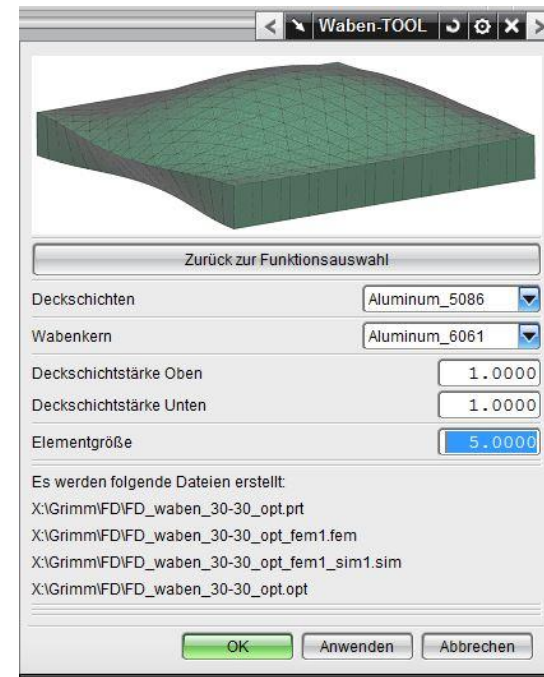
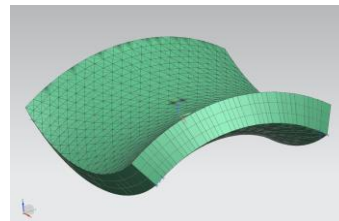
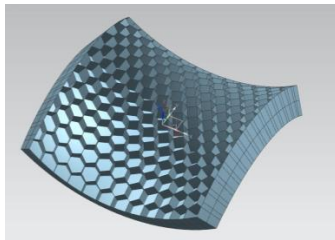
SOFTWARE TOOLS

LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

MODELING

Modeling

1. Meshing
2. Generating cover layers
3. Defining loads and bearings



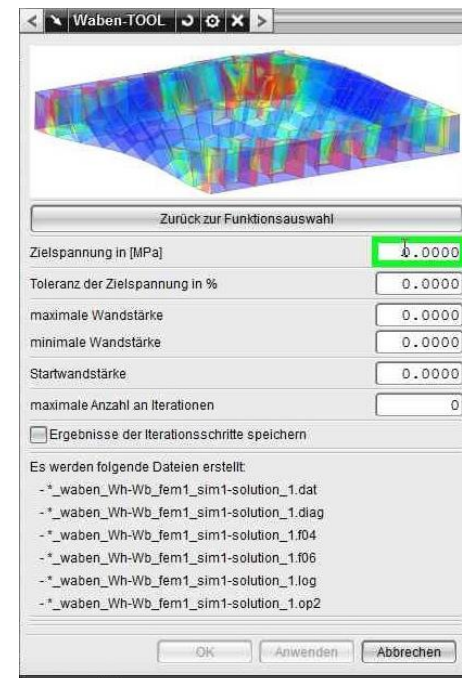
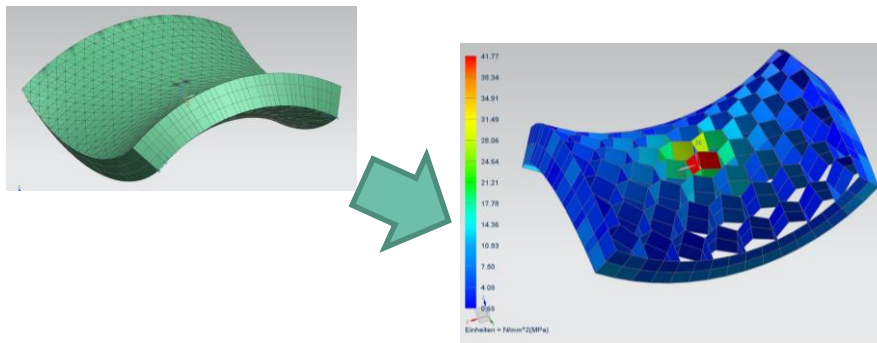
Screenshot of Fraunhofer Add-on

SOFTWARE TOOLS

LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

OPTIMIZATION

- Lightweight optimization by varying wall thickness
- Approach: homogeneous von-Mises-stresses in the part
- Consideration of AM-Design-guidelines

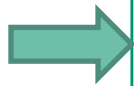


Screenshot of Fraunhofer Add-on

SOFTWARE TOOLS

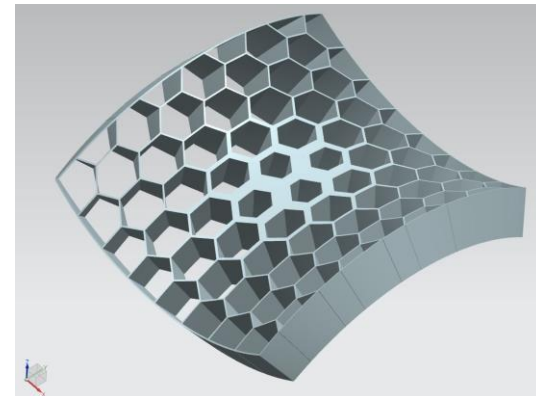
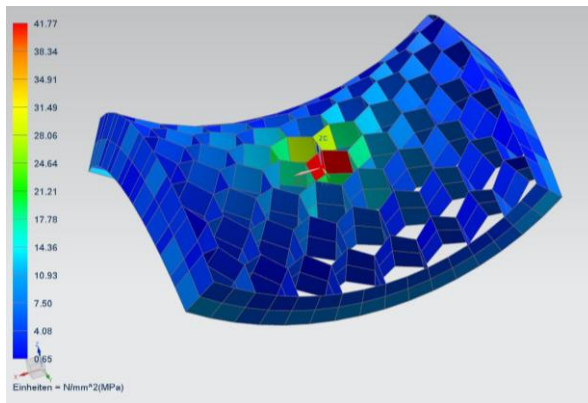
LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

GENERATING VOLUME PART



Generation
Volume Part

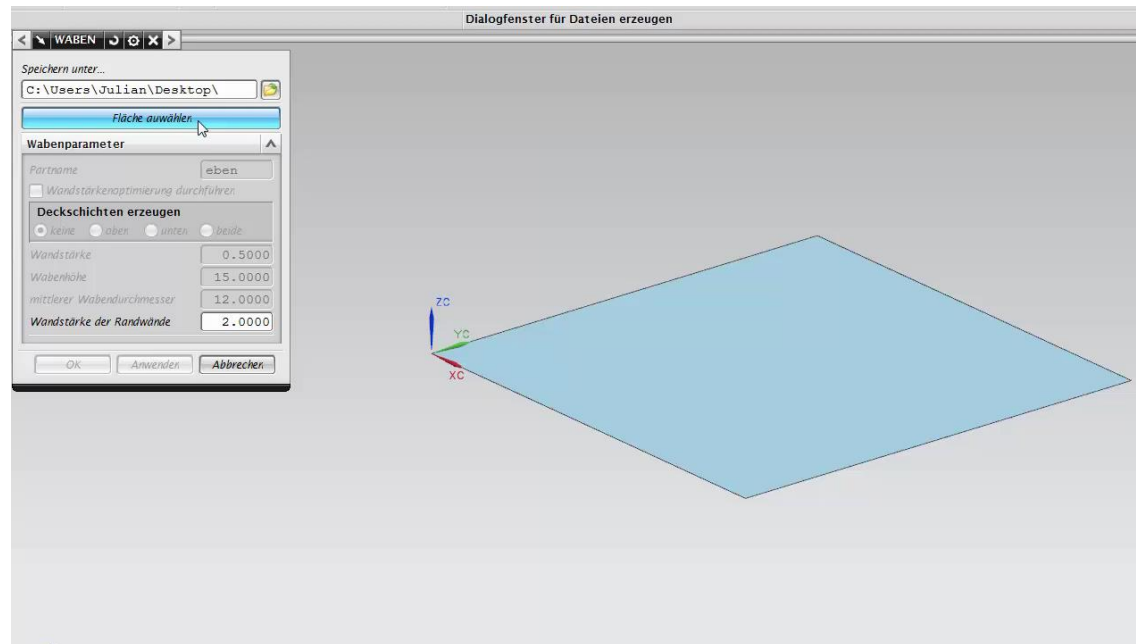
- Converting surface model into volume part
- Possibility to integrate additional functional components (e.g. inserts)



SOFTWARE TOOLS

LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

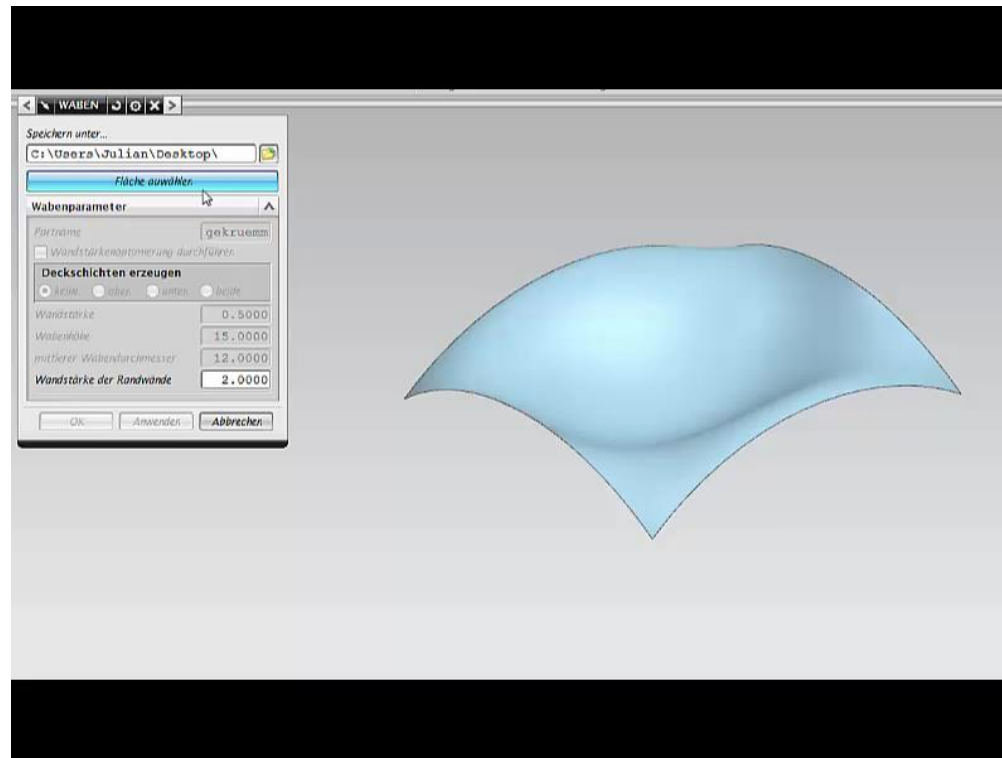
VIDEO



SOFTWARE TOOLS

LOAD-DEPENDENT OPTIMIZATION OF HONEYCOMBS

VIDEO



SUMMARY AND CONCLUSION

AMLAB 3-STEP-MODEL COVERING SOFT- AND HARDWARE

1

Potential analysis

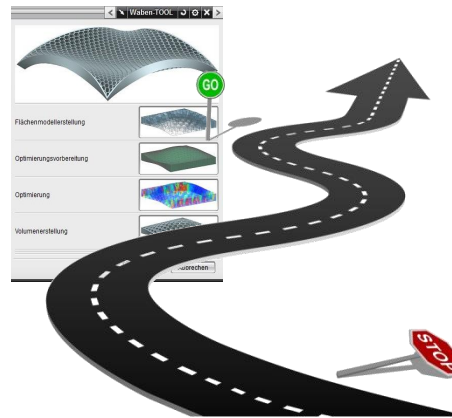
- Evaluation of company specific potential of additive manufacturing
- Identification of high potential parts and business units



2

Implementation

- Roadmap
- Organizational structure and department involvement
- Teach methods and provide tools



3

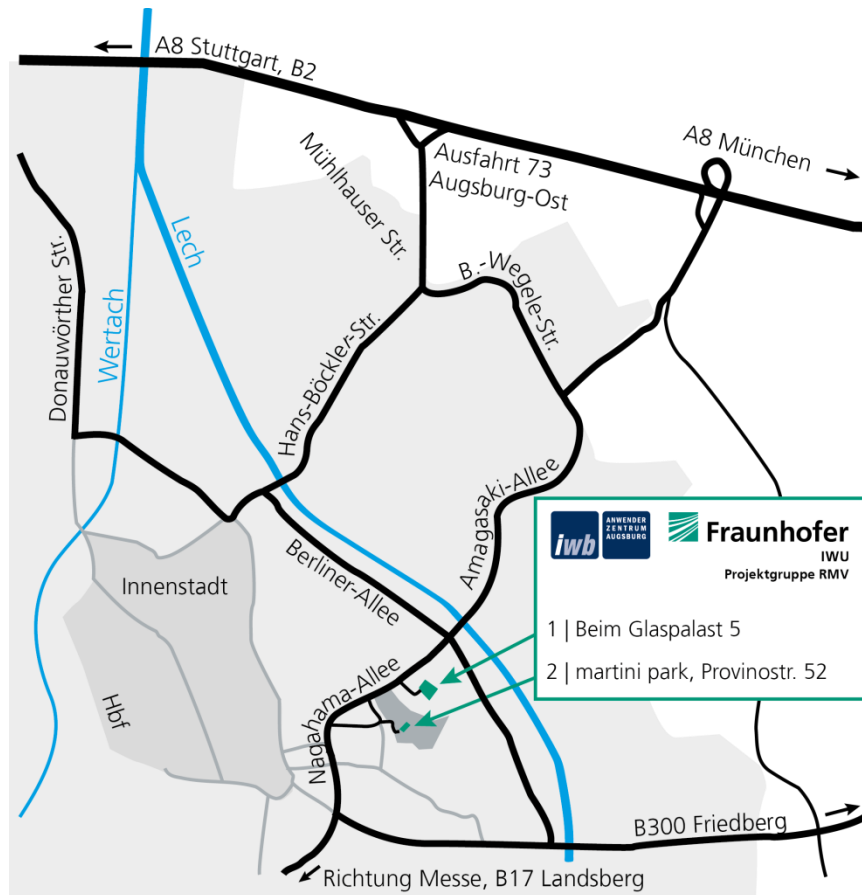
Production planning

- Layout
- Safety and health issues
- Production planning and control



THANK YOU!

HOW TO FIND US



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