# Additive design of laser-sintered polyamide lightweight structures for racing motorcycles

Technologietag 2019 - Leichtbau und Composites
27. 02. 2018, Schladming

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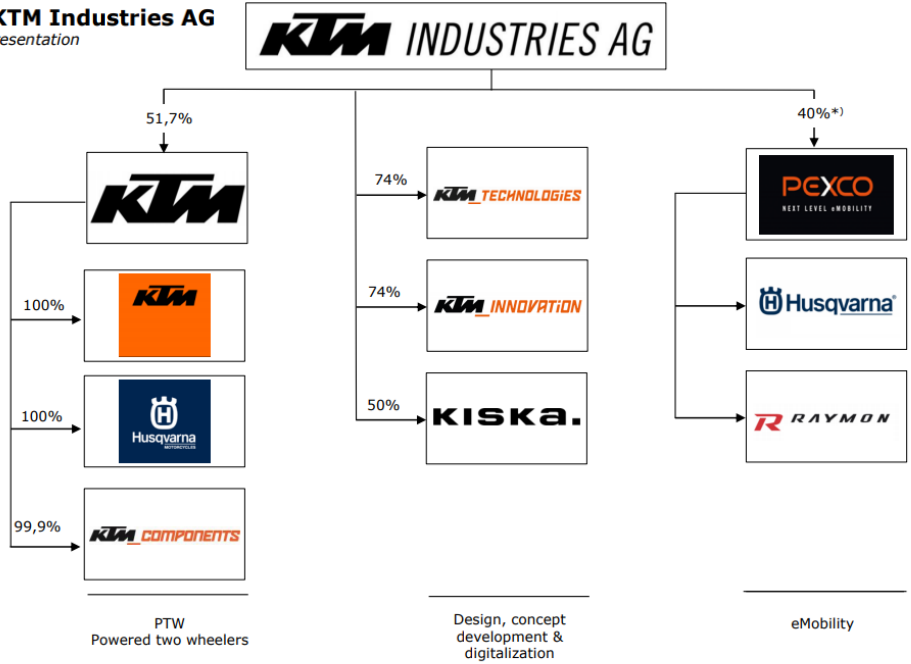
KTM_TECHNOLOGIES

# Agenda

- KTM Industries AG including KTM Technologies GmbH
- Introduction – Challenges
- Product development process
  - » Test Specimens
  - » Subcomponent
  - » Component
- Conclusion & Outlook

# Group Structure

**Group Structure of KTM Industries AG**
*as of 31/12/2018; simplified presentation*




Other shareholdings: PF Beteiligungsverwaltungs GmbH 100%, Acstyria Mobilitätscluster GmbH 12.3%
*) PEXCO GmbH „at equity"; 40% are held by Platin 1483 GmbH (family Puello), 20% are held by Pierer Industrie AG

# KTM-TECHNOLOGIES GmbH

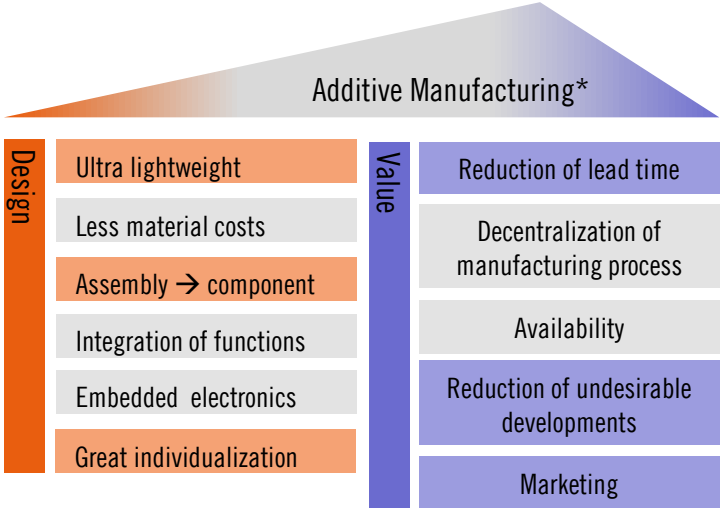
- Founded in 2008
- Nucleus: KTM X-Bow complete vehicle development
- Approx. 100 highly qualified specialists
- Location - Anif near Salzburg, Austria
- 2018 Cooperation with Christian Doppler Laboratory with IKL / JKU

- Focus in concept development of vehicles
- Industrial sectors: automotive / sports / medical engineering / mechanical engineering / smart consumer electronics
- Integrated process chain from the idea to functional prototypes
- Innovation and technology incubator within KTM group


Photographer: Jesús Robledo

# Introduction

- Expectations on additive manufacturing

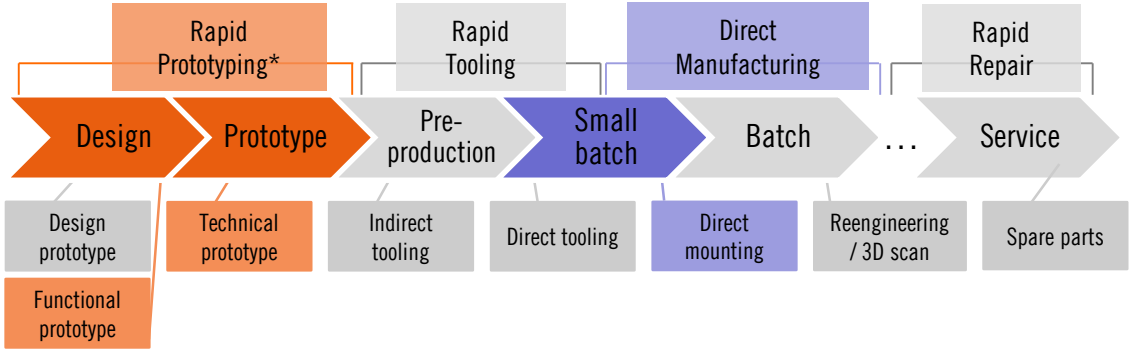



*taken over and revised, R. Lachmayer, R. B. Lippert, T. Fahlbusch, "3D-Druck beleuchtet – Additive Manufacturing auf dem Weg in die Anwendung", Springer Vieweg, Berlin- Heidelberg, 2016


CFRP front fairing

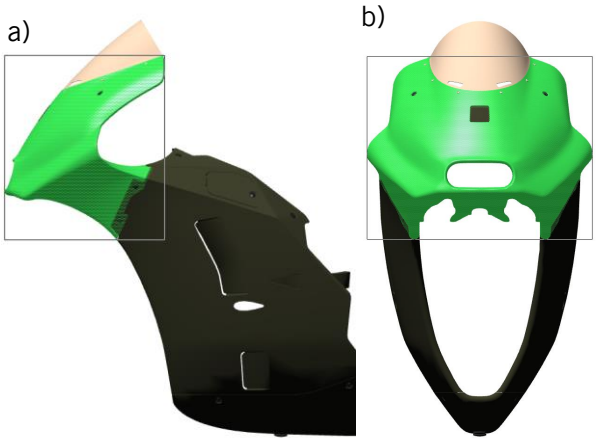
# Introduction

- Product development process




*taken over and revised, R. Lachmayer, R. B. Lippert, T. Fahlbusch, “3D-Druck beleuchtet – Additive Manufacturing auf dem Weg in die Anwendung”, Springer Vieweg, Berlin- Heidelberg, 2016

- e.g. front fairing




Motorcycle top fairing
side view (a) and front view (b)

# Introduction

- Laser Sintering Systems


Source: EOS

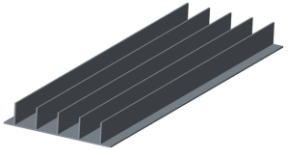
| System | Length | Width | Height | Laser type |
|---|---|---|---|---|
| P396 | 340 mm | 340 mm | 600 mm | 1 $CO_2$ x 70 W |


Source: EOS

| System | Length | Width | Height | Laser type |
|---|---|---|---|---|
| P770 | 700 mm | 380 mm | 580 mm | 2 $CO_2$ x 70 W |

# Product Development Process

Generic structure



Sub component



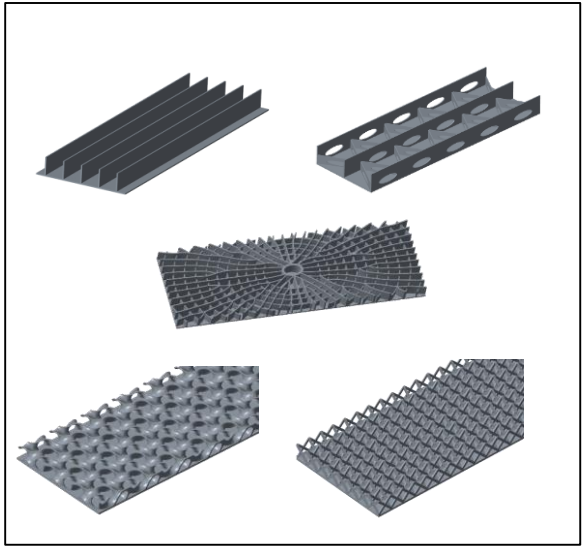
Component



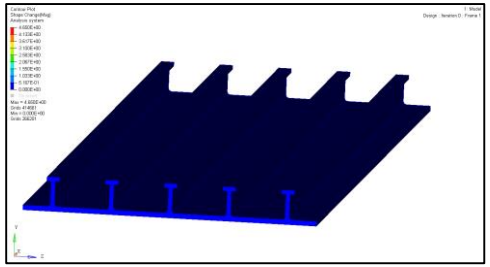
Assembly

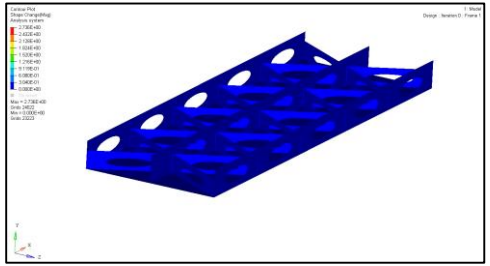
# Design of generic structures

- Development of generic geometrical concepts

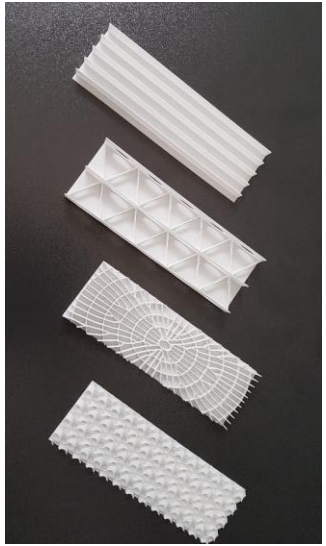


Design directions





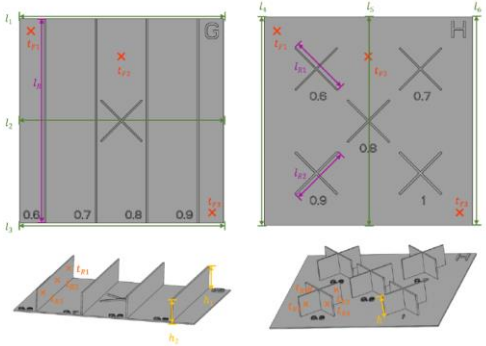
Shape & size optimization



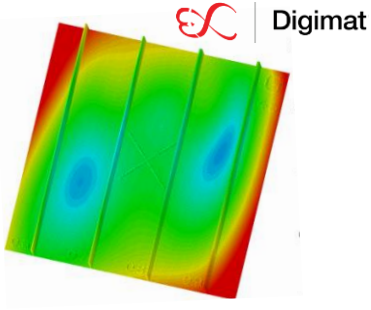
Manufacturing study

# Thin-walled specimens

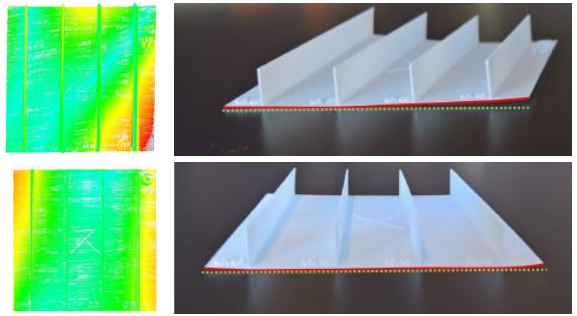
- Printing quality and dimensional accuracy of test specimens




Measuring point definition




Process Simulation

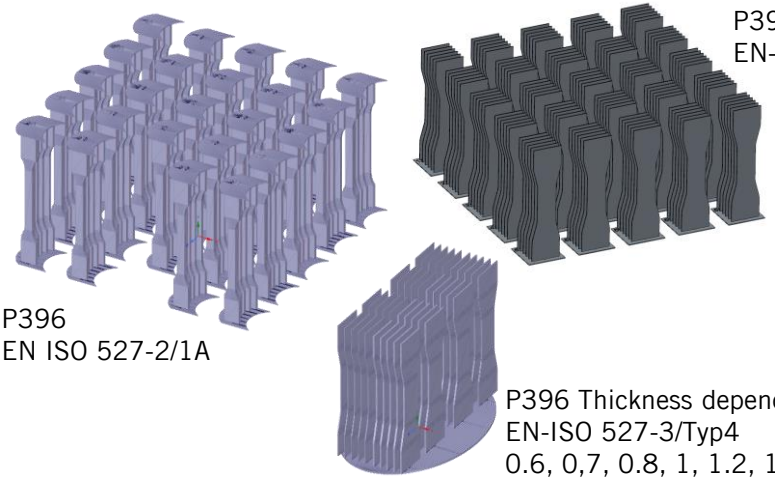


3D-scan and printing result without (top) and with process simulation (bottom)

A. Mad, „Prozesssimulation und Geometrieadaptierung dünnwandiger, lasergesinterter Leichtbaustrukturen“, (Master Thesis), Technical University Vienna, Vienna, 2018

# Build Area & Wall Thickness Investigation

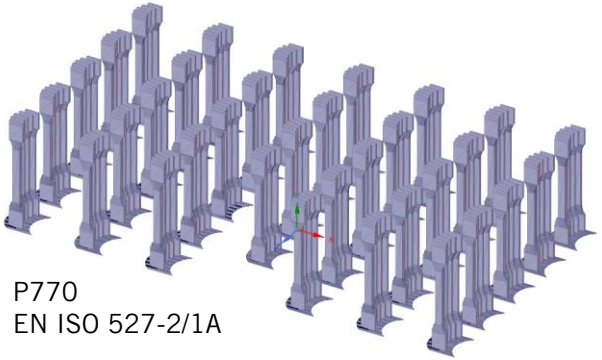
- Mechanical properties, system and material characterization



P396 Thin-walled test specimen
EN-ISO 527-3/Typ4

P396
EN ISO 527-2/1A

P396 Thickness dependcey
EN-ISO 527-3/Typ4
0.6, 0,7, 0.8, 1, 1.2, 1.6, 1.8, 2 mm

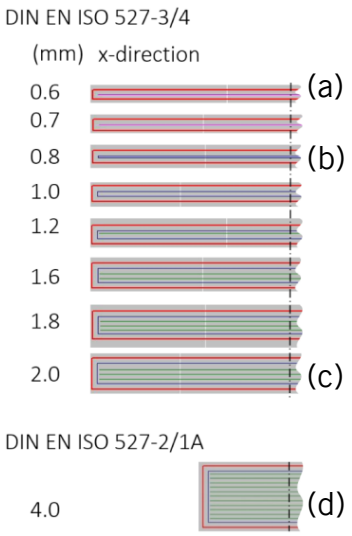


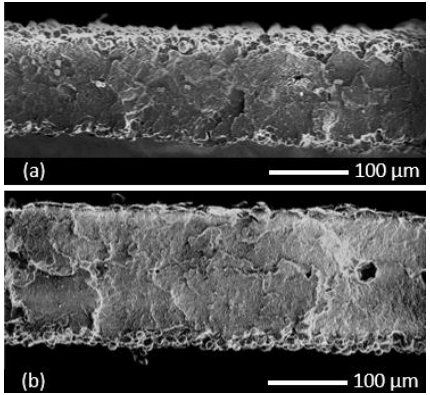
P770
EN ISO 527-2/1A

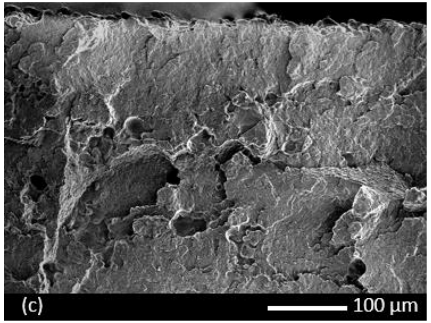
D. Tasch, A. Mad, R. Stadlbauer and M. Schagerl „Thickness dependency of mechanical properties of laser-sintered polyamide lightweight structures", *Additive Manufacturing*, vol. 23, pp. 25–33, 2018.

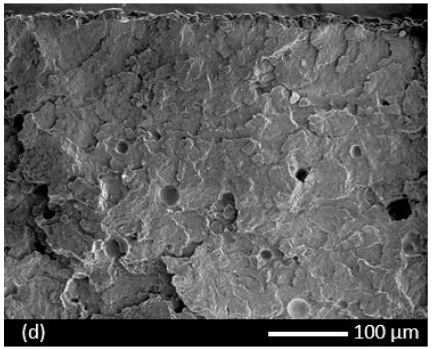
# Build Area & Wall Thickness Investigation

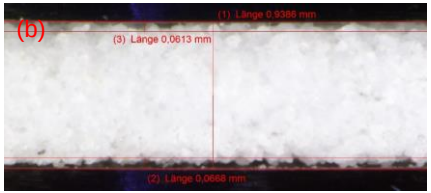
- Material characterization – SEM/LM



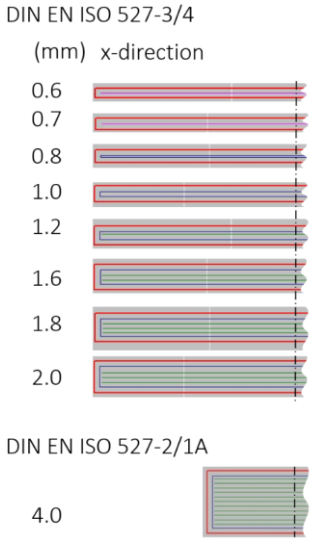



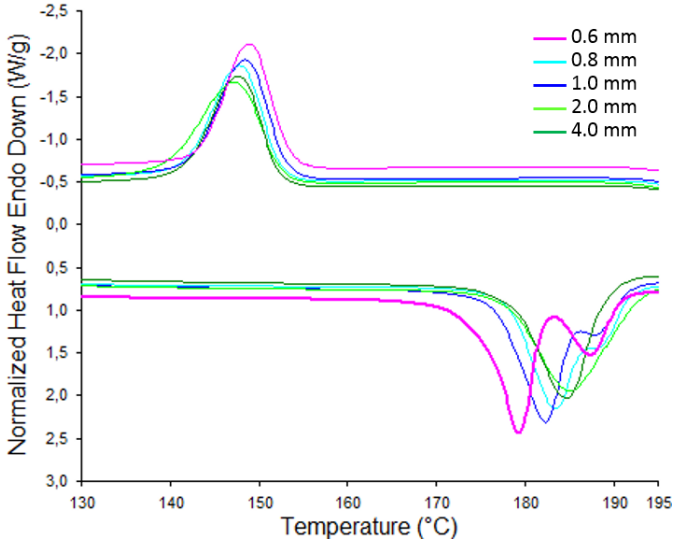




D. Tasch, A. Mad, R. Stadlbauer and M. Schagerl „Thickness dependency of mechanical properties of laser-sintered polyamide lightweight structures", *Additive Manufacturing*, vol. 23, pp. 25–33, 2018.

# Build Area & Wall Thickness Investigation

- Material characterization - DSC

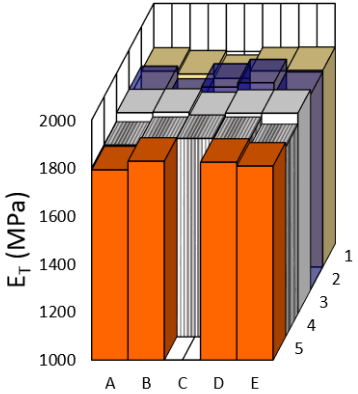


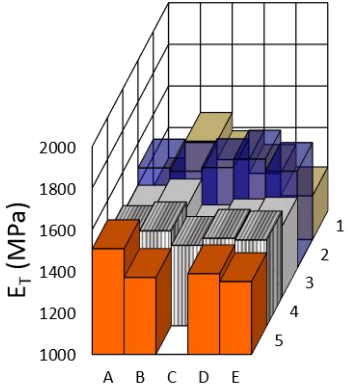

D. Tasch, A. Mad, R. Stadlbauer and M. Schagerl „Thickness dependency of mechanical properties of laser-sintered polyamide lightweight structures", *Additive Manufacturing*, vol. 23, pp. 25–33, 2018.

# Build Area & Wall Thickness Investigation

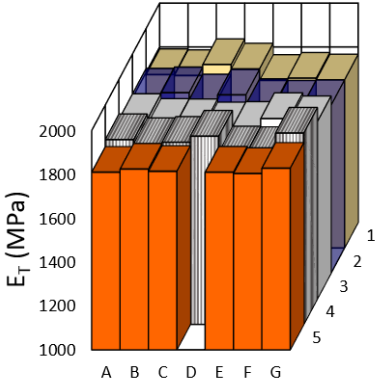
- Results: Young's modulus tensile




P396
EN ISO 527-2/1A




P396 Thin-walled test specimen
EN-ISO 527-3/Typ4

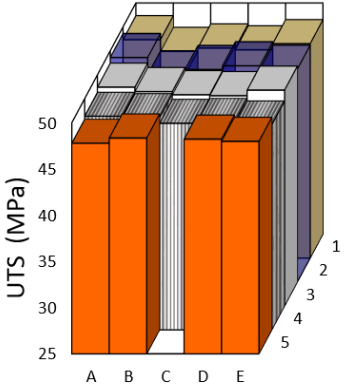



P770
EN ISO 527-2/1A

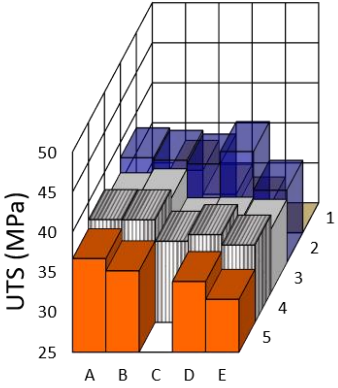
D. Tasch, A. Mad, R. Stadlbauer and M. Schagerl „Thickness dependency of mechanical properties of laser-sintered polyamide lightweight structures", *Additive Manufacturing*, vol. 23, pp. 25–33, 2018.

# Build Area & Wall Thickness Investigation

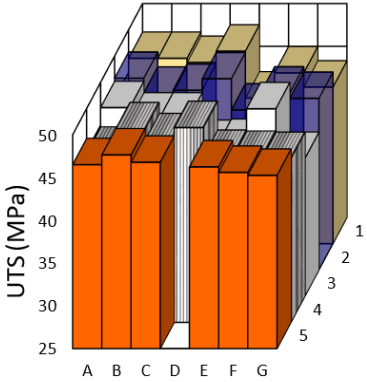
- Results: Ultimate tensile strength




P396
EN ISO 527-2/1A




P396 Thin-walled test specimen
EN-ISO 527-3/Typ4

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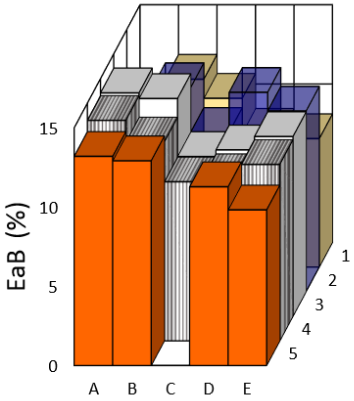
# Build Area & Wall Thickness Investigation

- Results: Elongation at break

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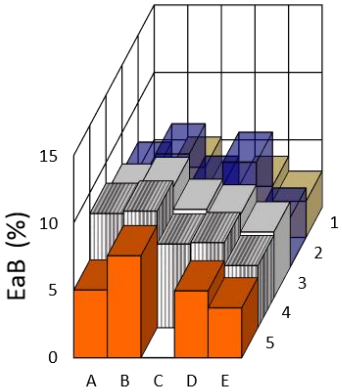
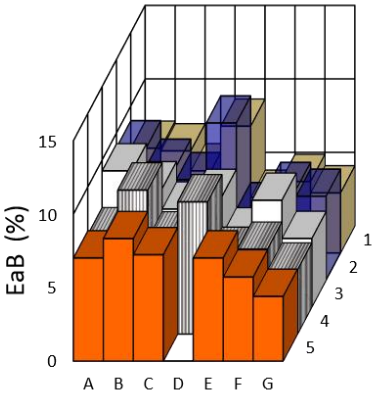
EN ISO 527-2/1A




P396 Thin-walled test specimen
EN-ISO 527-3/Typ4

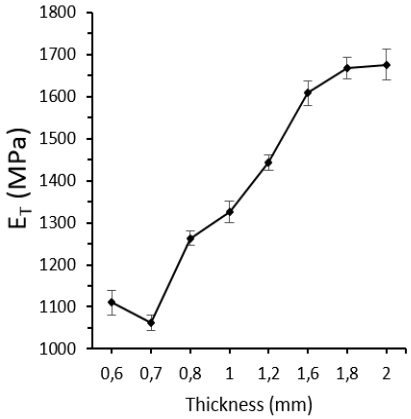


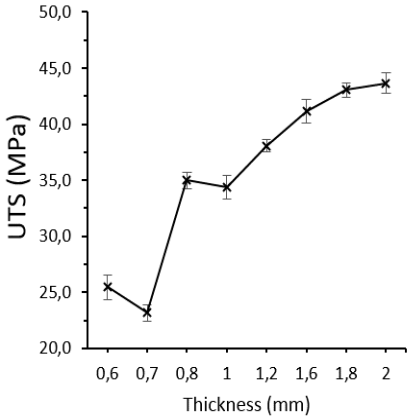

P770
EN ISO 527-2/1A

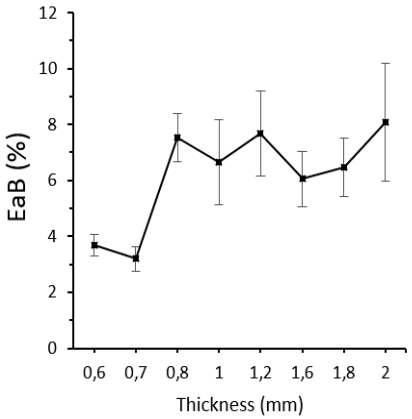
D. Tasch, A. Mad, R. Stadlbauer and M. Schagerl „Thickness dependency of mechanical properties of laser-sintered polyamide lightweight structures", *Additive Manufacturing*, vol. 23, pp. 25–33, 2018.

# Build Area & Wall Thickness Investigation

- Results: Overview wall thickness investigation



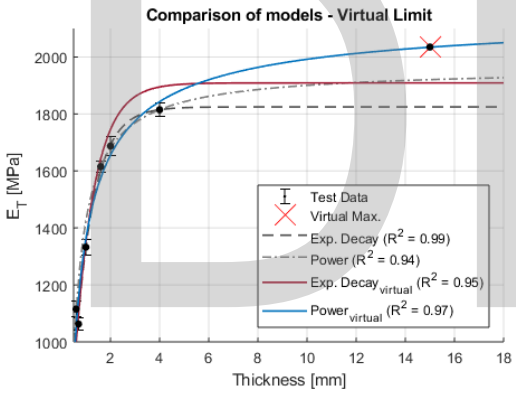




P396 Thickness dependency
EN-ISO 527-3/Typ4 0.6, 0.7, 0.8, 1, 1.2, 1.6, 1.8, 2 mm

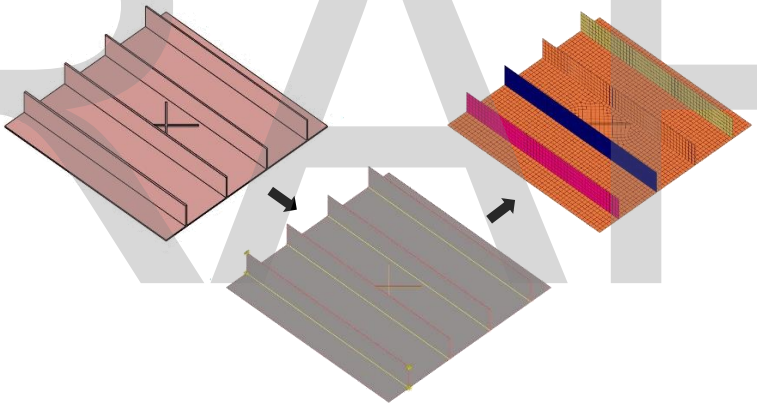
D. Tasch, A. Mad, R. Stadlbauer and M. Schagerl „Thickness dependency of mechanical properties of laser-sintered polyamide lightweight structures", *Additive Manufacturing*, vol. 23, pp. 25–33, 2018.

# Integration into Simulation Process

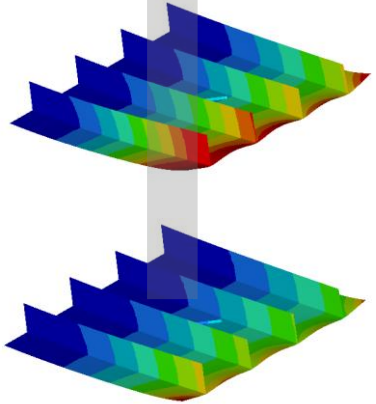
- Mapping of mechanical properties




Mathematical curve fitting



Thickness depended Young's modulus midsurface mapping



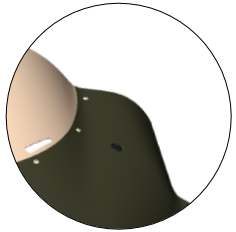
Displacement with (top) and without (bottom) mapping

# Product Development Process

Generic structure



Sub component



Component



Assembly

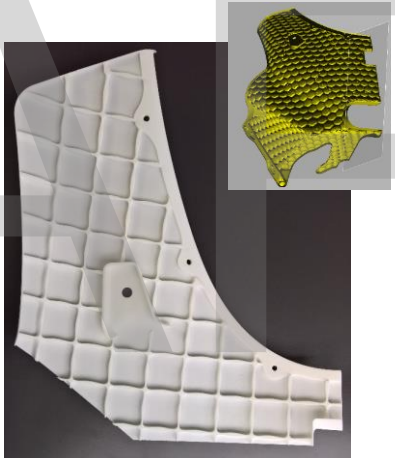
# CAD-Capabilities / Subcomponent

- Design approaches

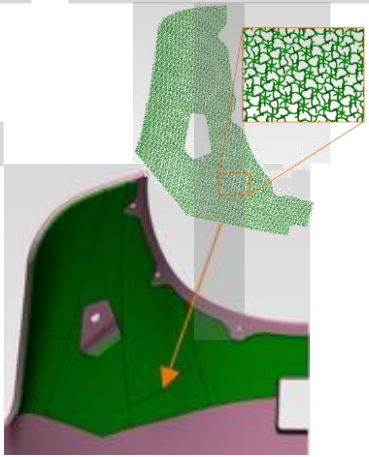


Ribbed design

Direct topology design



Pattern mapping design



Lattice based design

# Product Development Process

Generic structure



Sub component

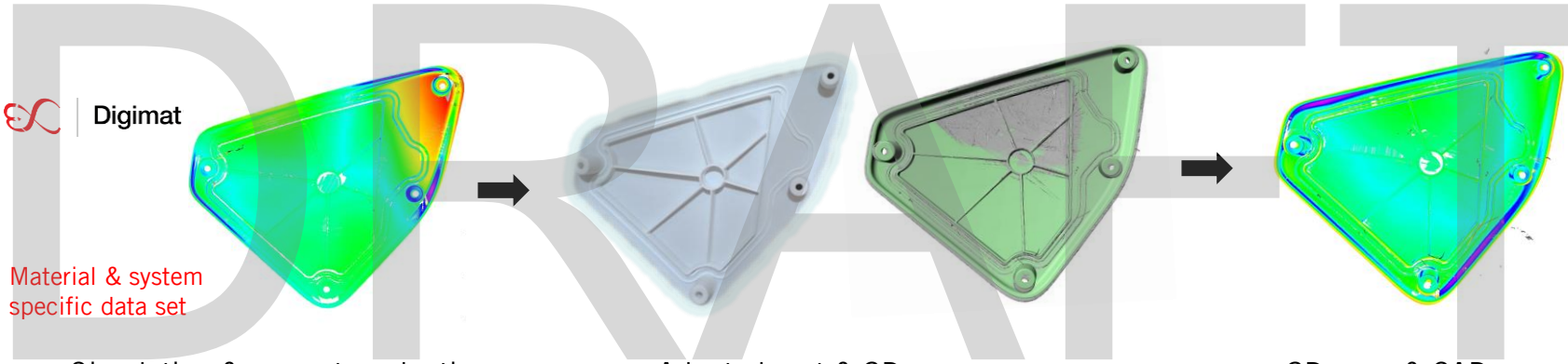


Component

Assembly

# Thin-walled component

- Printing quality and dimensional accuracy of a component



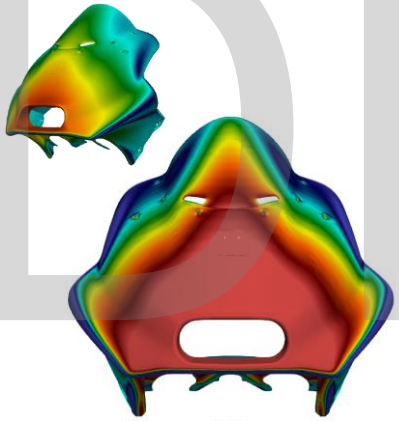

Process Simulation & geometry adaption | Adapted part & 3D-scan | 3D-scan & CAD comparison

A. Mad, „Prozesssimulation und Geometrieadaptierung dünnwandiger, lasergesinterter Leichtbaustrukturen“, (Master Thesis), Technical University Vienna, Vienna, 2018

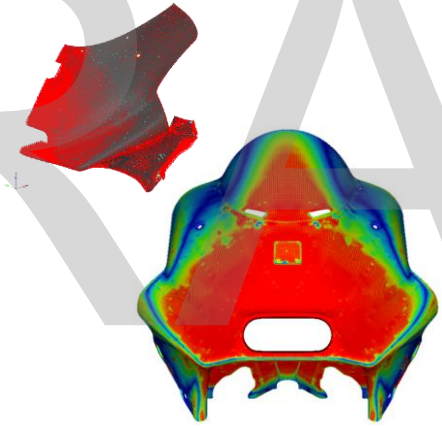
# Simulation Approach - Component

- Loads and Design Spcae

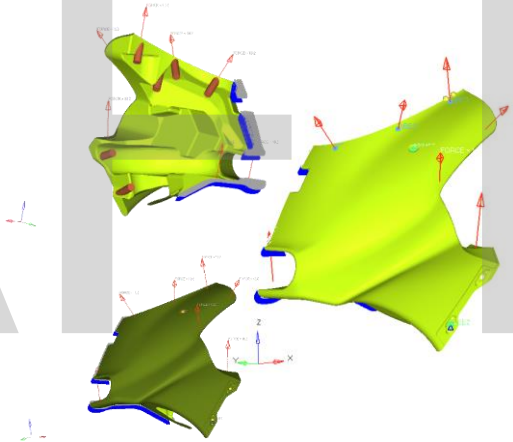




CFD pressure distribution



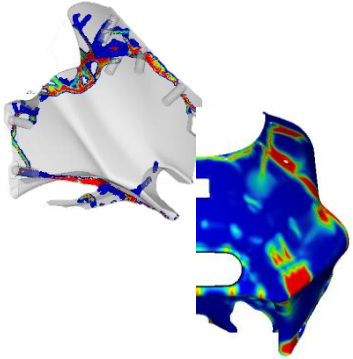
FEM pressure distribution



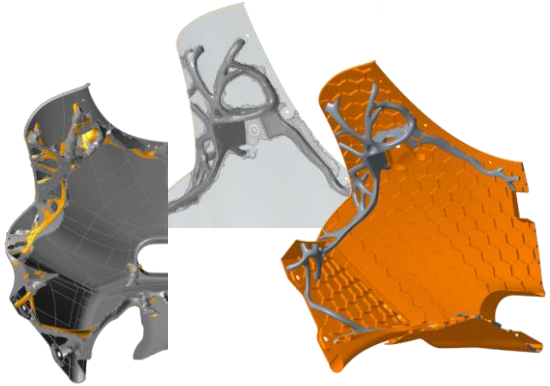
Structural optimization design space

# Structural Optimization

- Structural optimization with e.g. direct topology design approach



Structural optimization



Geometry creation & pattern mapping

Combined CAD for print data

# Product Development Process

Generic structure



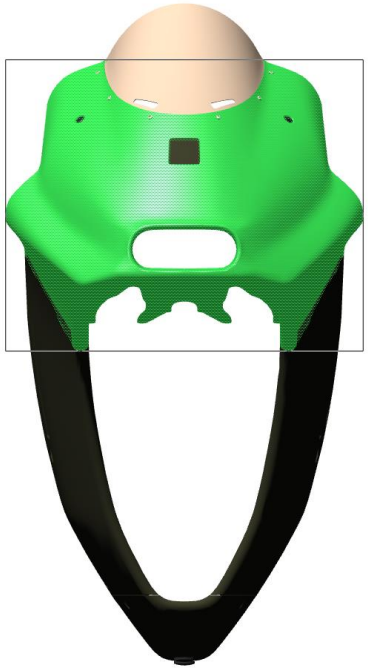
Sub component



Component

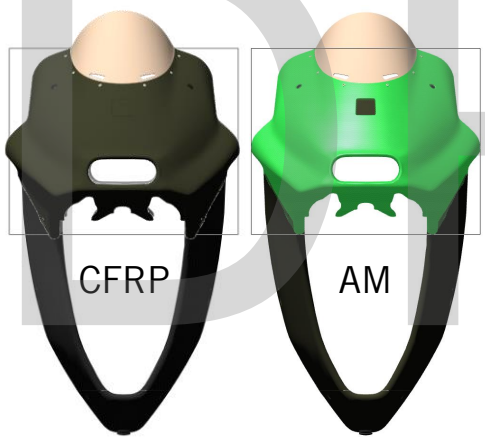


Assembly

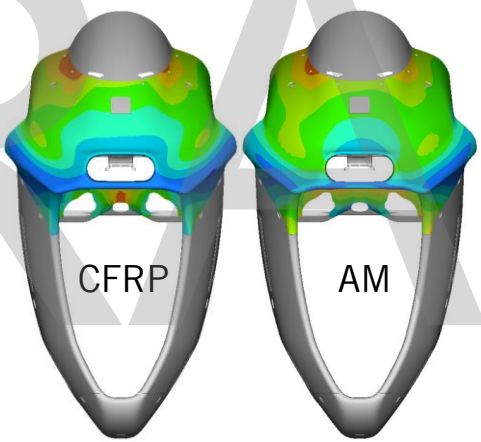


# Finite Element Analysis of Assembly

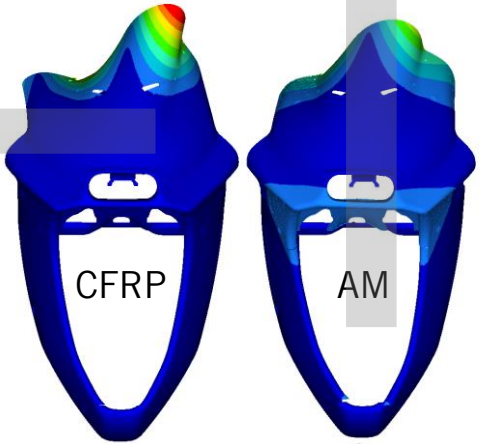
- Comparison of results




Comparison simulation setup




Displacement




Eigenmode

# Additive Manufacturing & Assembly

- Printing and Assembly

P770 powder cake

Unpacking of front fairing


Race track testing
>333 km/h Top Speed

# Conclusion

- For achieving lightweight and high performing AM structures a combination of material science, design and simulation methods is needed.
- Thickness dependency of AM material based on thermal history and process parameters has to be considered.
- Design of thin walled structures has to consider process simulation and FEA.
- Design freedom is time consuming in engineering and shows limits of CAE software solutions.
- A front fairing for racing motorcycles can be designed in PA2200 (PA12), simulated and additively manufactured for race track testing (>333 km/h).

# Outlook

- Impact dynamic properties → LS Dyna MAT24
- Crash Simulation
- Breaking behavior

Bird strike


Test matrix for MAT24 card

4a Impetus

# THANK YOU FOR YOUR ATTENTION

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