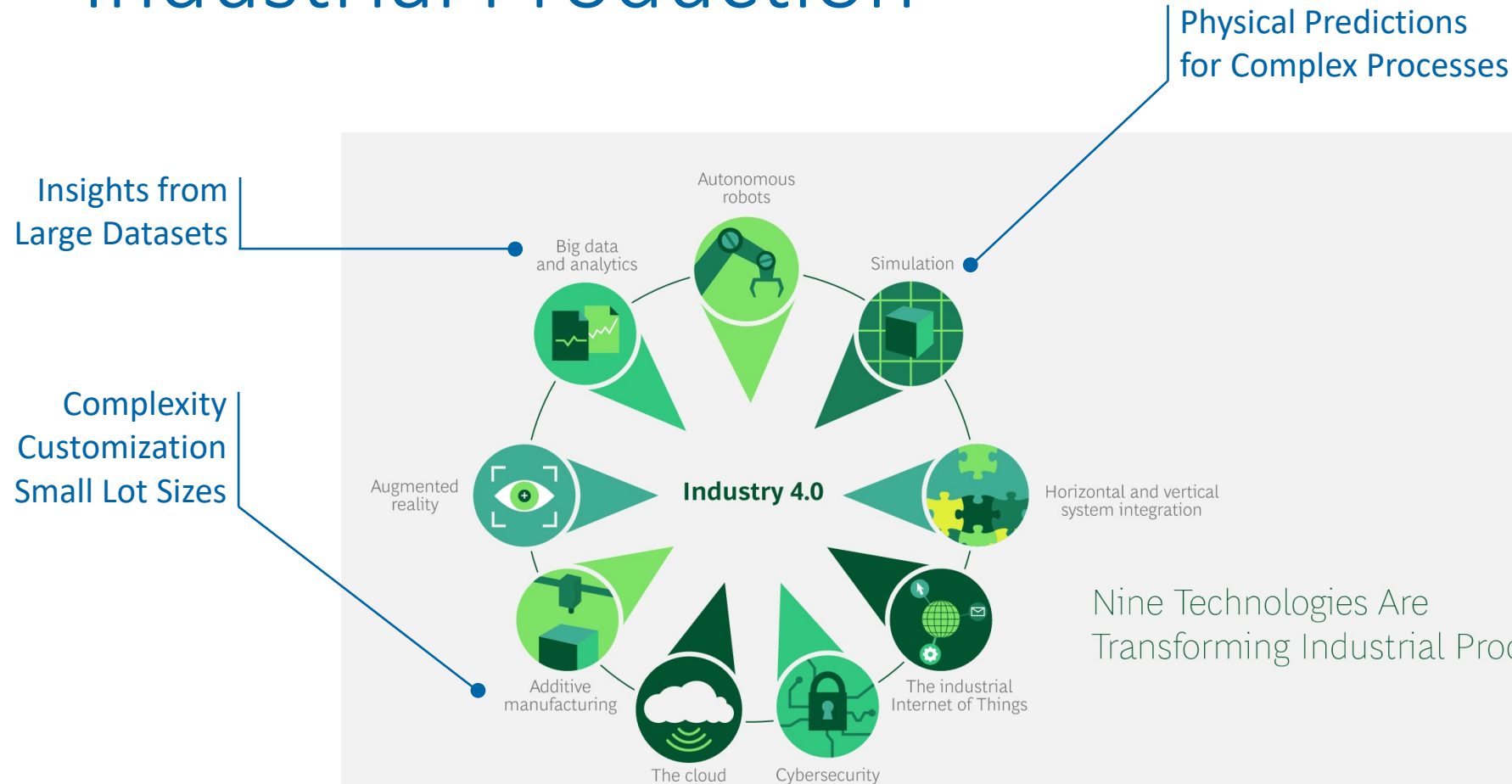


Process Simulation for Distortion Prediction: Material Data and Calibration

Dr. Thomas Mayer

ZHAW – Institute of Mechanical Systems

Digital Transformation in Industrial Production



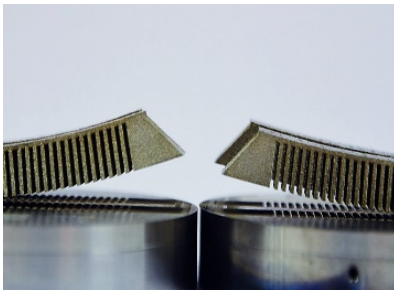
Nine Technologies Are
Transforming Industrial Production

Source: BCG analysis.

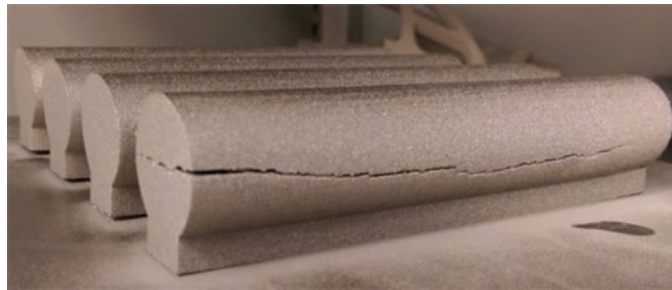
Boston Consulting Group, 2019.

Failed Parts → High Costs

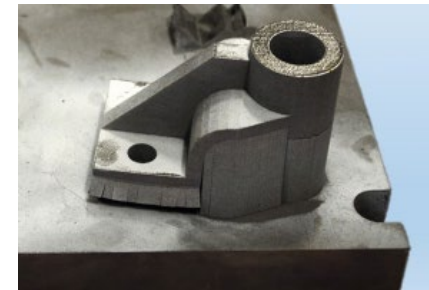
- Distorted / failed parts ~100 kCHF / year (SME)
- Thermo-mechanical process simulation
 - distortion prediction for compensation
 - assessment of manufacturability
 - optimisation of build configuration



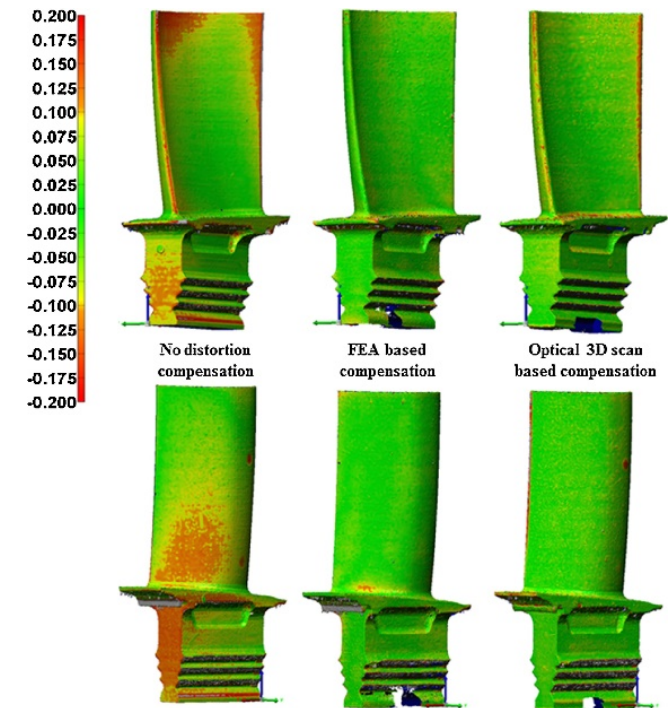
Fraunhofer ILT



Renishaw



America Makes

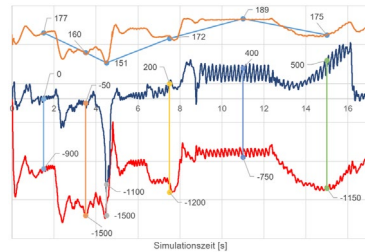
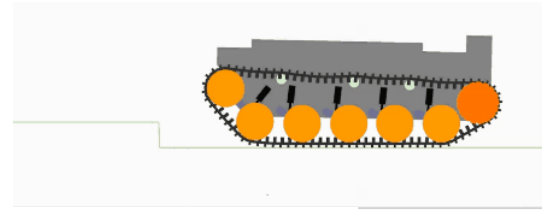


Affazov et al. (2017). *AM*, 17(Oct),15-22

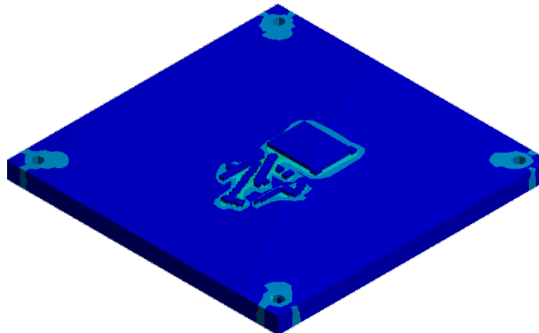
Qualitative Simulations



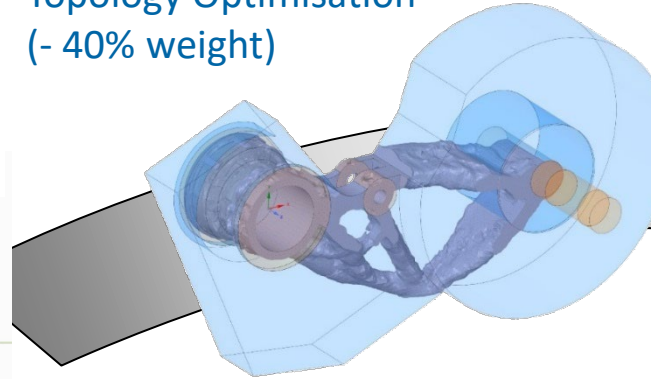
Load Cases



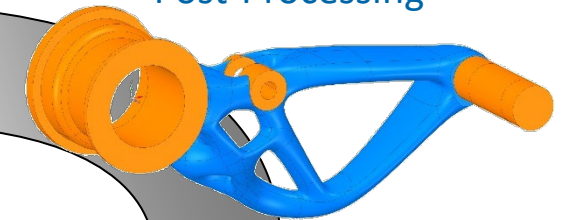
Process Validation



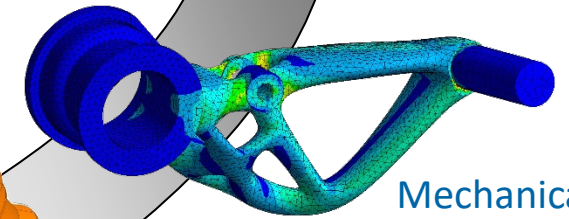
Topology Optimisation
(- 40% weight)



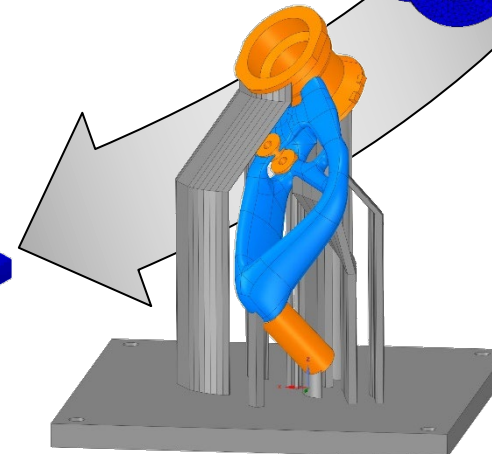
Post-Processing



Mechanical
Validation

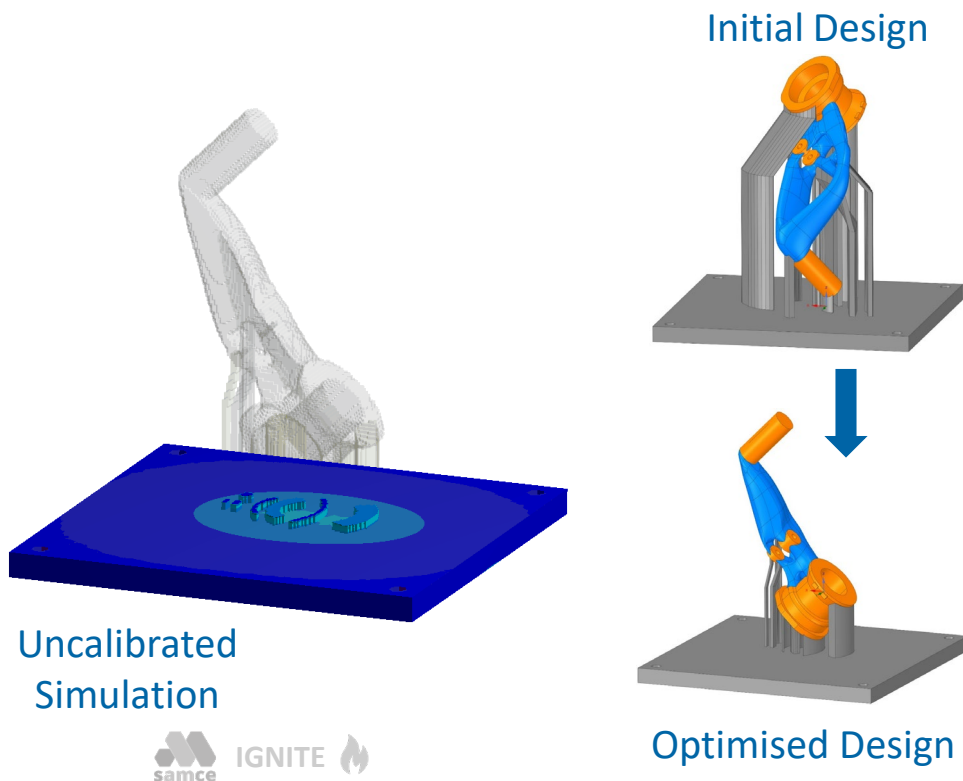


Preparation of
AM Process

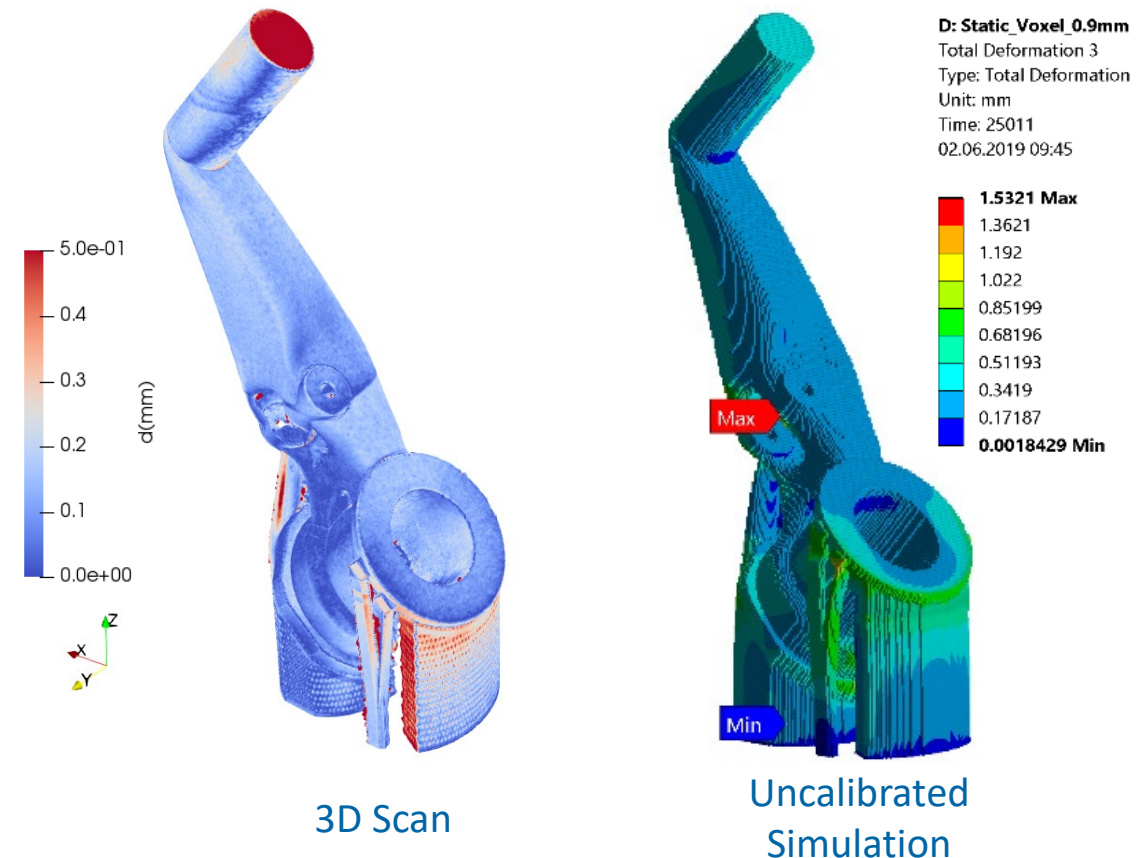


Qualitative Simulations

- Optimisation of build configuration
→ distortions reduced by factor 3

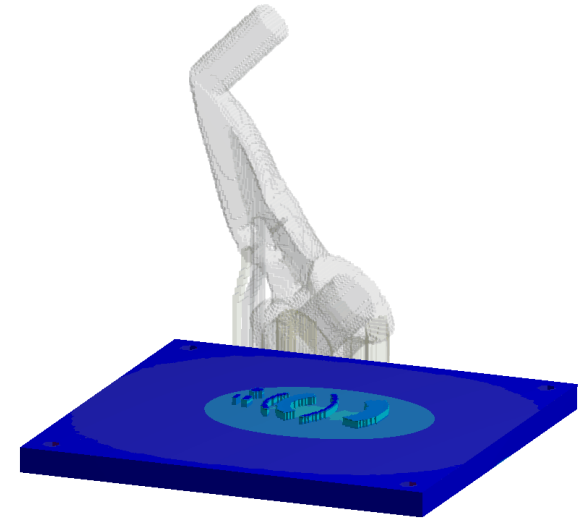
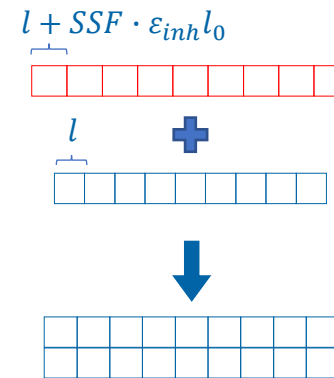


- Quantitative distortions off by factor 2

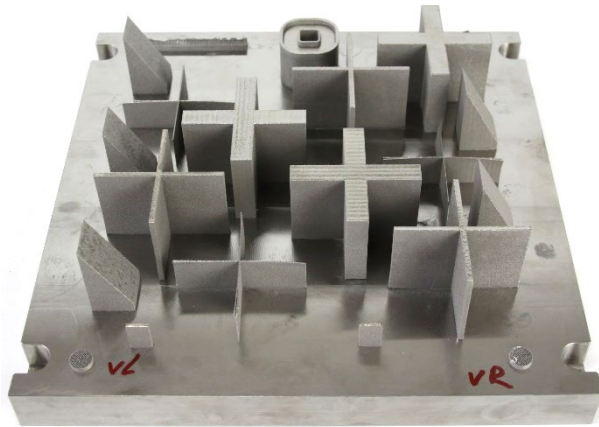


Quantitative Simulation

- Lumped layer approach & layer-wise activation
- Inherent strain approach
→ calibration of inherent strains
- Thermo-mechanical approach
→ calibration of thermal model



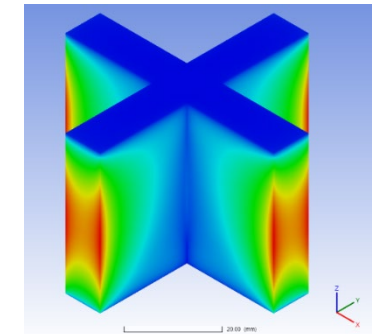
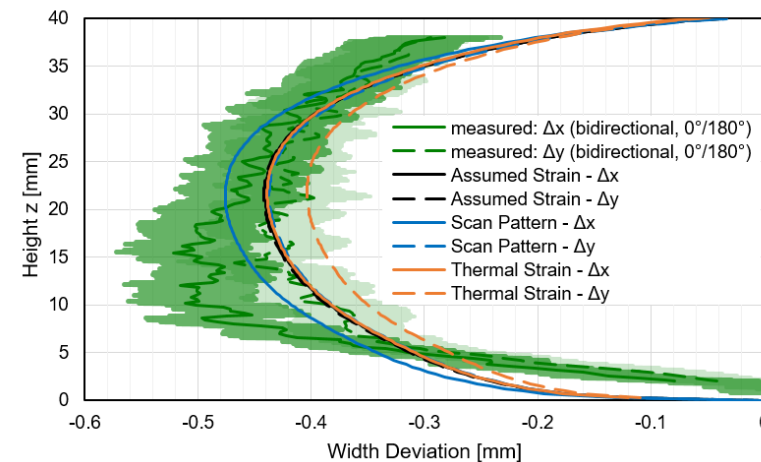
Conventional Calibration



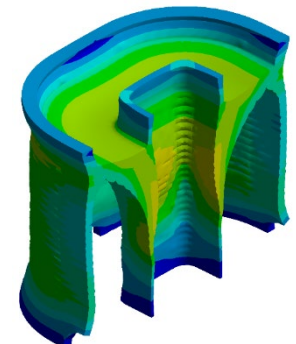
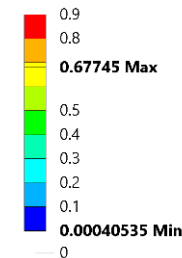
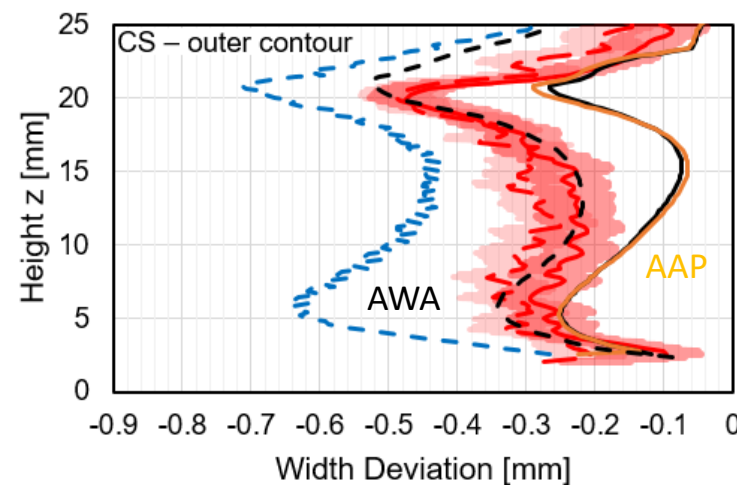
Mayer et al. (2020). Heliyon, 6(5), e03987.

- Mechanical approach
→ extrapolation limited
- Thermo-mechanical approach
→ acceptable accuracy

Calibration

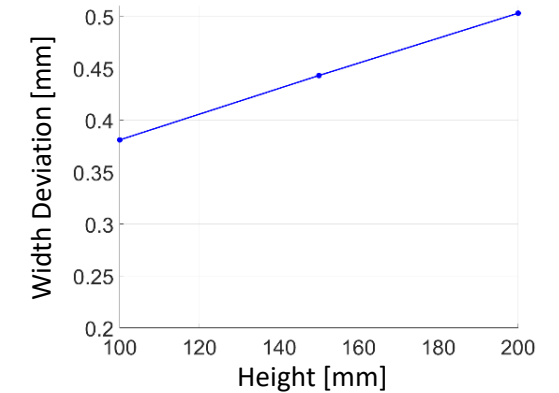
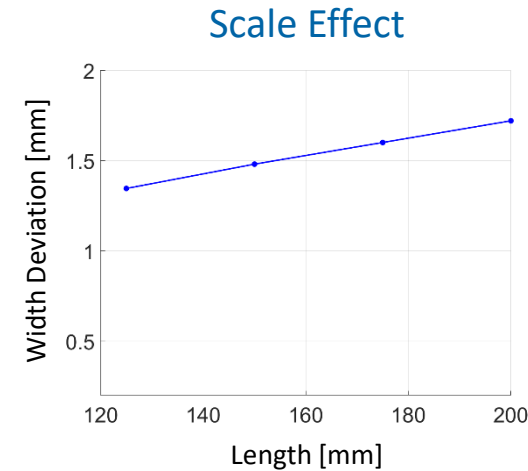


Validation

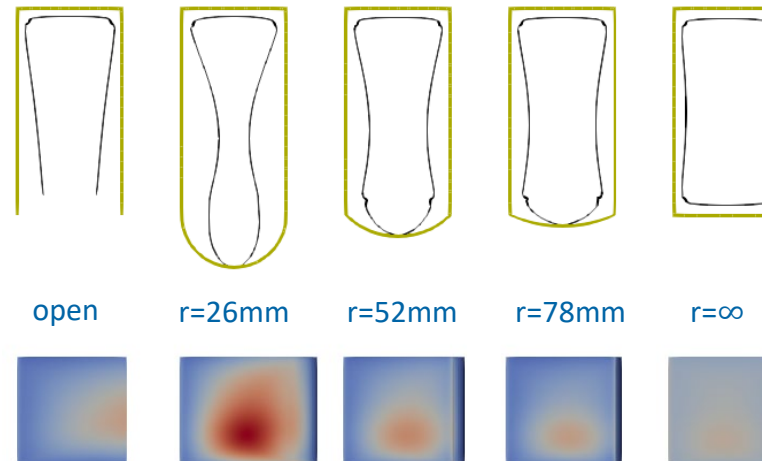


Distortion Mechanisms

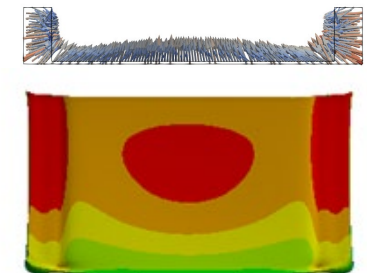
- Distortion =
Temperature Gradient \Leftrightarrow Structural Stiffness
 - Scale effect
 - Wall thickness
 - Change of cross-section
 - Support stiffness



Support Stiffness

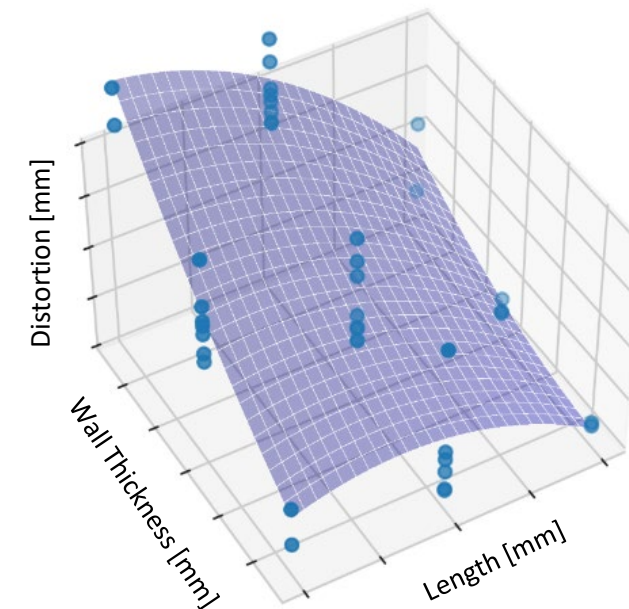
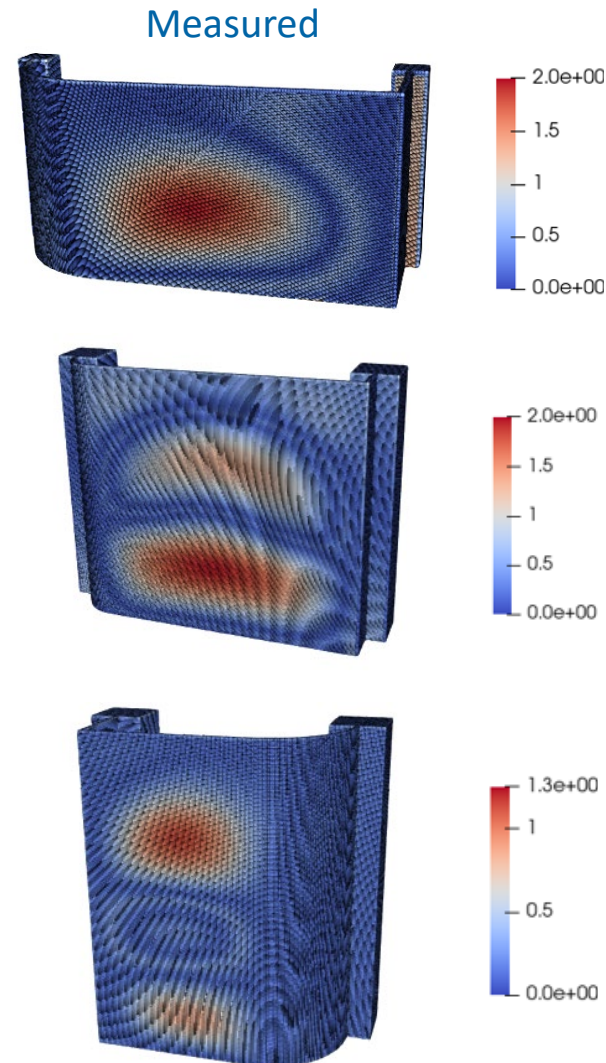
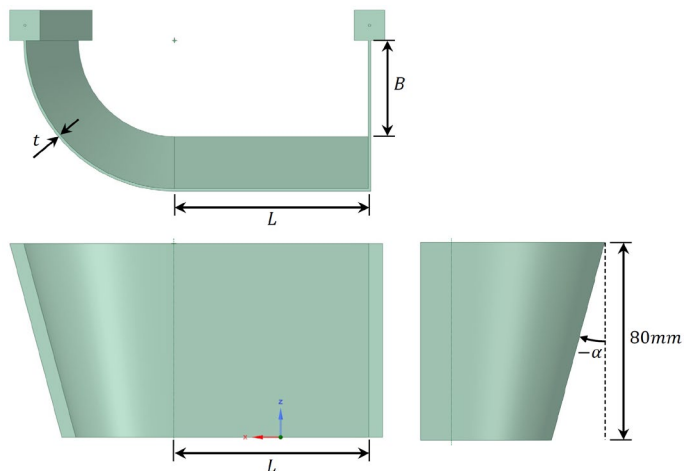


Change of
Cross-section

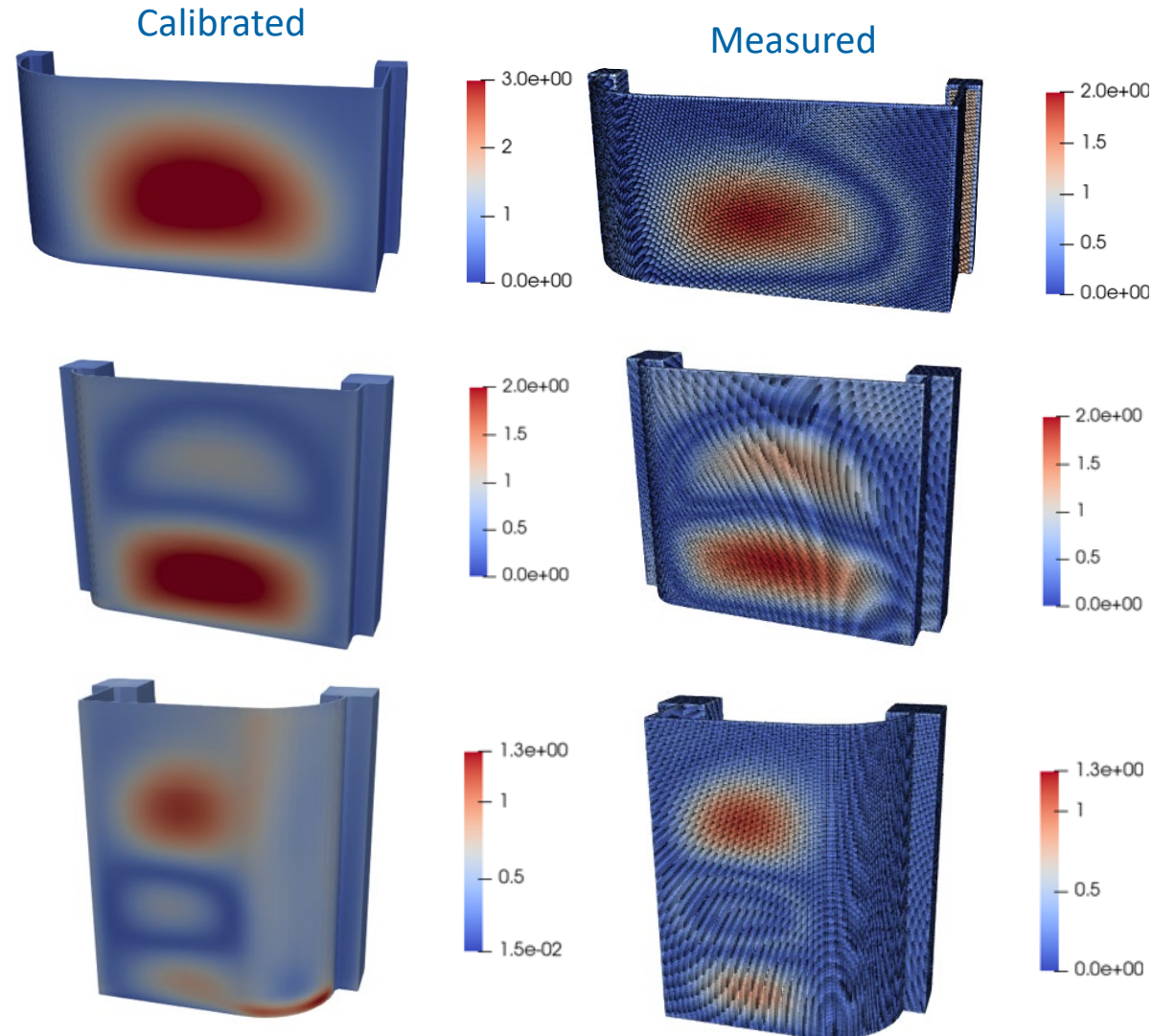


Distortion Mechanisms

- Distortion = Temperature Gradient \Leftrightarrow Structural Stiffness
 - Distortion = Geometry-dependent
- Component-like calibration!



Calibration for Thin-Walled Parts

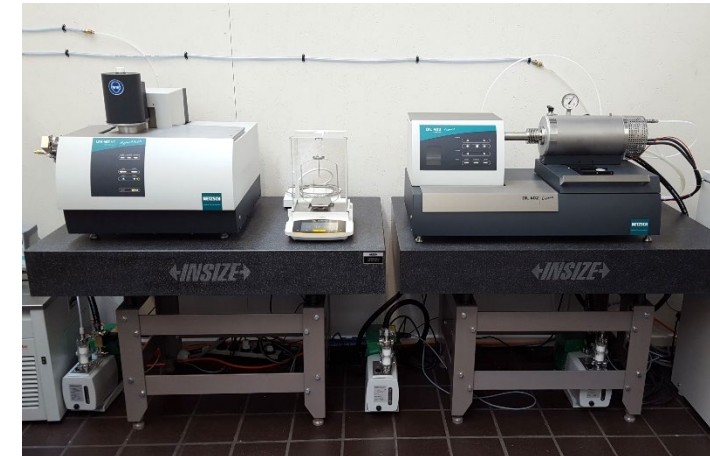


Material Data @ ZHAW

- Hot Tensile Testing (-80 °C to 1100 °C, < 250 kN)
- Thermo-Physical Characterisation
 - thermal expansion (< 2000 °C)
 - thermal conductivity (< 1250 °C)
 - specific heat capacity (< 2000 °C)
 - density (< 2000 °C)
- Constitutive Modelling for FEA
- Planned for 2023
 - High-speed dilatometry & tensile testing (< 10^5 K/s, 100 mm/s)
 - SLM machine for in-situ calibration




Servo-hydraulic machines

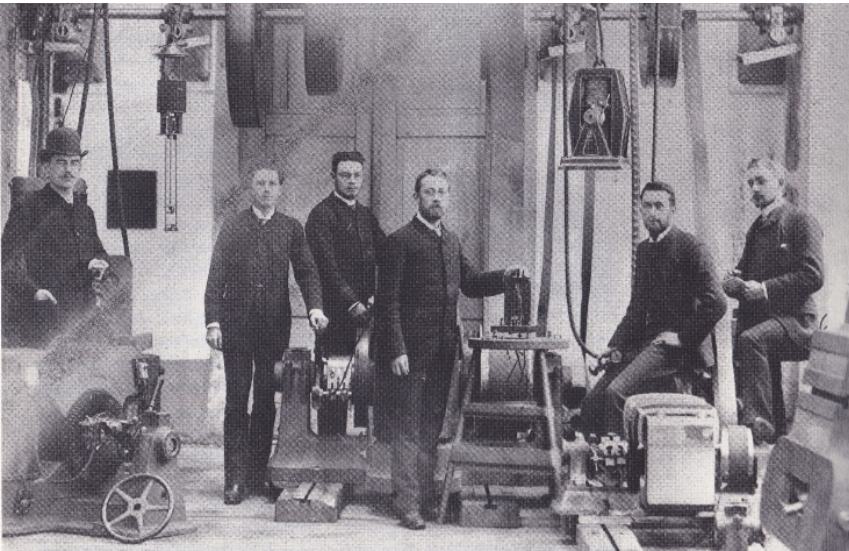


LFA – Laser Flash Analyzer, DIL – High Temperature Dilatometer

- Process simulation can improve quality of SLM parts
- Geometry-dependent calibration & appropriate material data needed
- Dedicated experiments need to be developed



Thank you for your attention!



Dr. Thomas Mayer

ZHAW Zurich University of Applied Sciences

IMES Institute of Mechanical Systems

E thomas.mayer@zhaw.ch

T +41 58 934 4731