



**AACHEN CENTER
FOR ADDITIVE
MANUFACTURING**



**RWTHAACHEN
UNIVERSITY**



Design optimization of a cylinder head under high thermomechanical loading using the design freedom offered by additive manufacturing

Johannes Willkomm | 28.09.2022

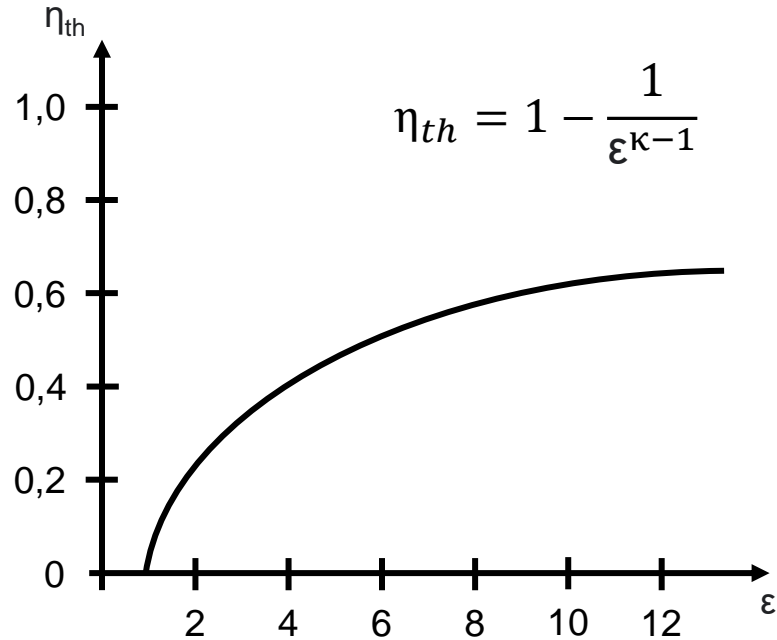
ACAM

Motivation



Improved combustion and lower emission due to lower temperatures

Otto cycle



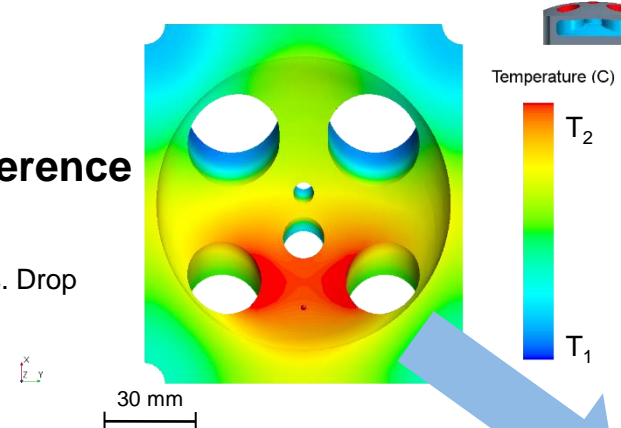
- Thermal efficiency limited by ϵ
- ϵ limited by knocking



Model combustion chamber cylinder head

Reference

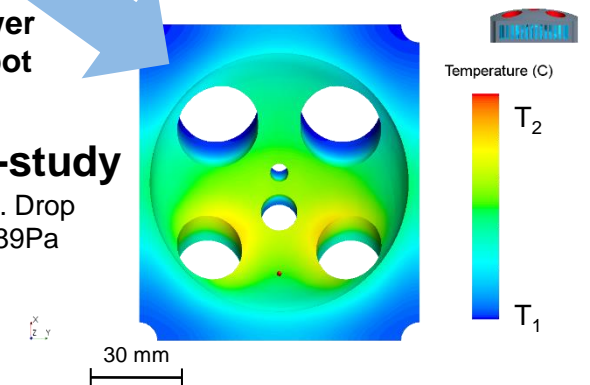
Press. Drop
P



30 - 40K lower
temp hot spot

Pre-study

Press. Drop
P + 389Pa





Laser Powder Bed Fusion: Functional improvement by exploiting design potentials

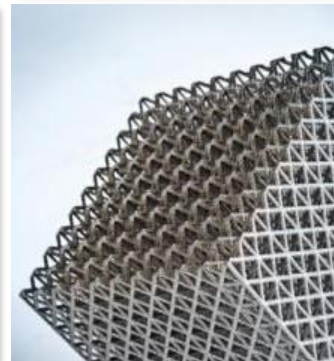
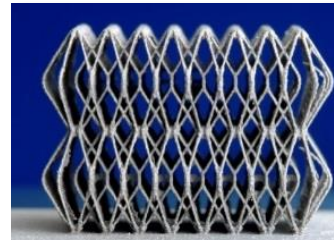
Additional Design Freedom

- Overhangs/undercuts
- Internal spaces
- Lighter hollow or half open lattice structure and 2.5D lattice structure
- Functional components
- Monolithic design

- Design complexity does not come at additional cost during the production process with additive manufacturing techniques
- Traditional design restrictions do not apply anymore



e.GO Mobile
AG

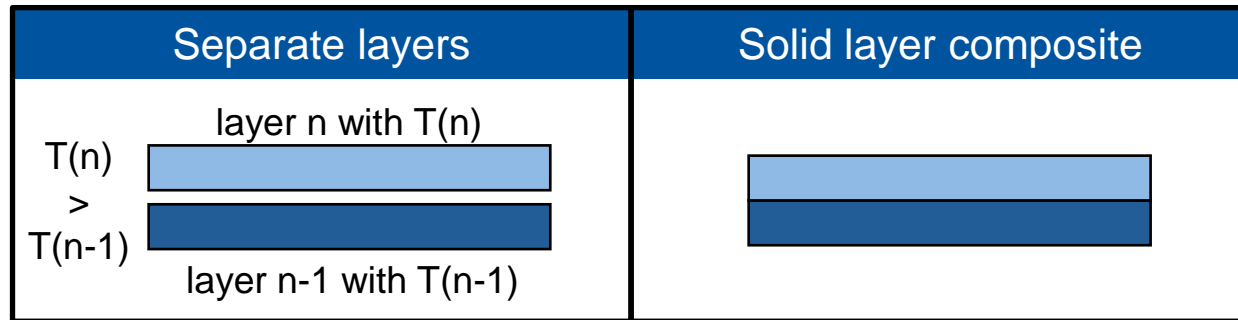




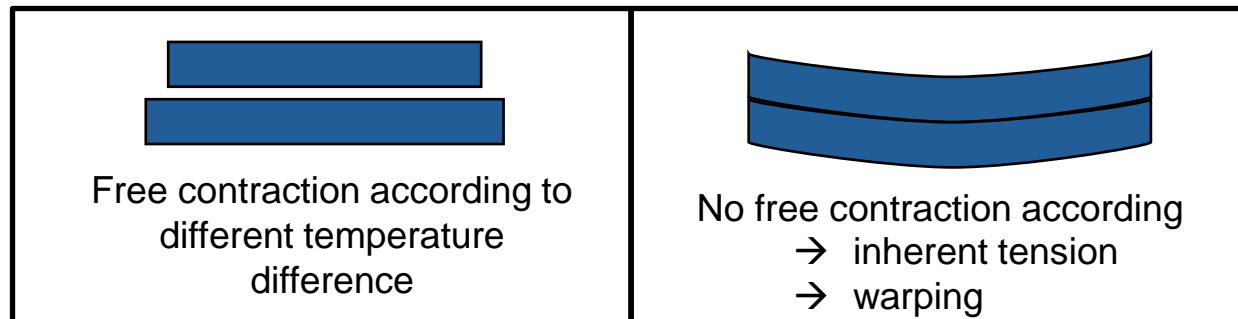
Laser Powder Bed Fusion: design restrictions

Physical effect

Buildup of residual stresses

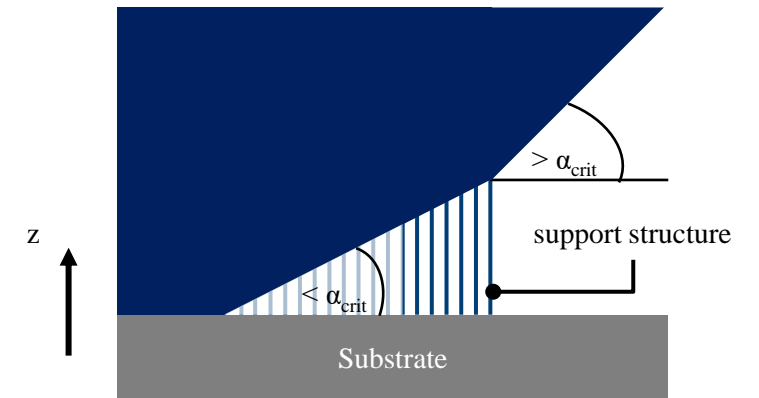


↓ cooling

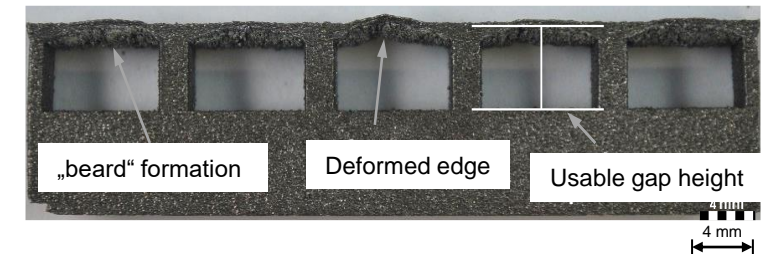


Design guidelines

Support structure

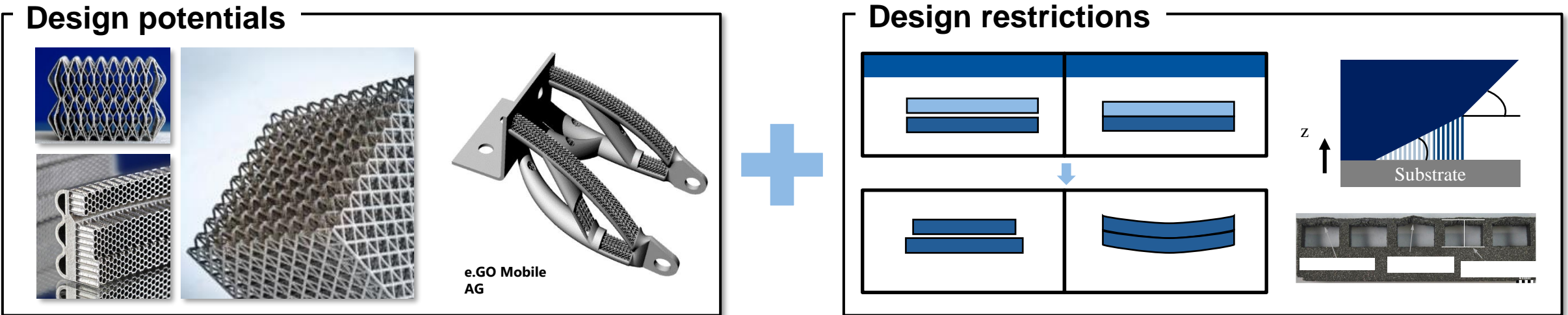


Unsupported bridge width

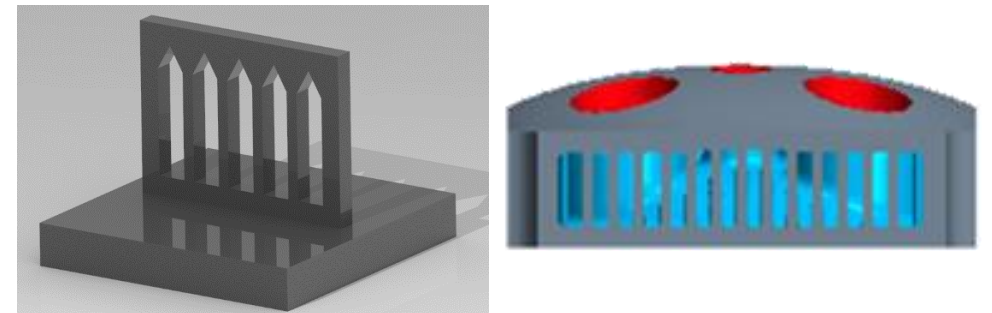




Exploiting design potentials in consideration of the design restrictions



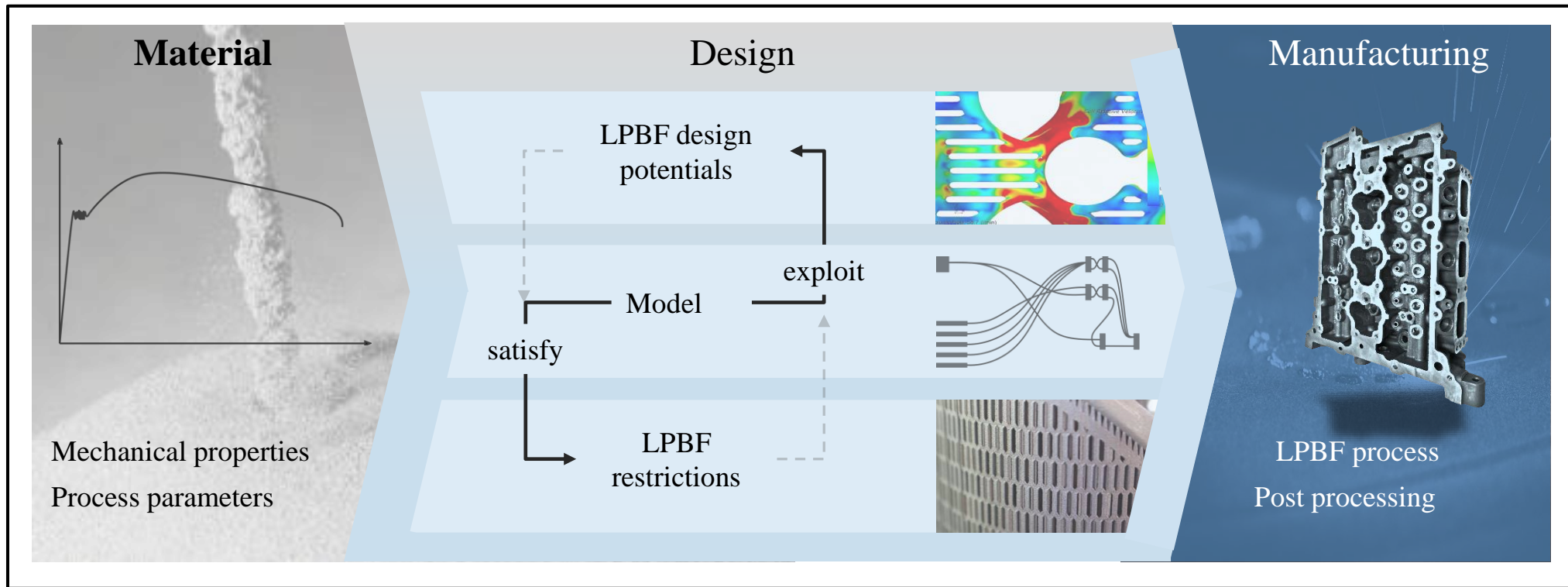
Internal cooling structures guarantee the processability of Overhanging structures by LPBF and improve the cooling Characteristics of the cylinder head.



Approach

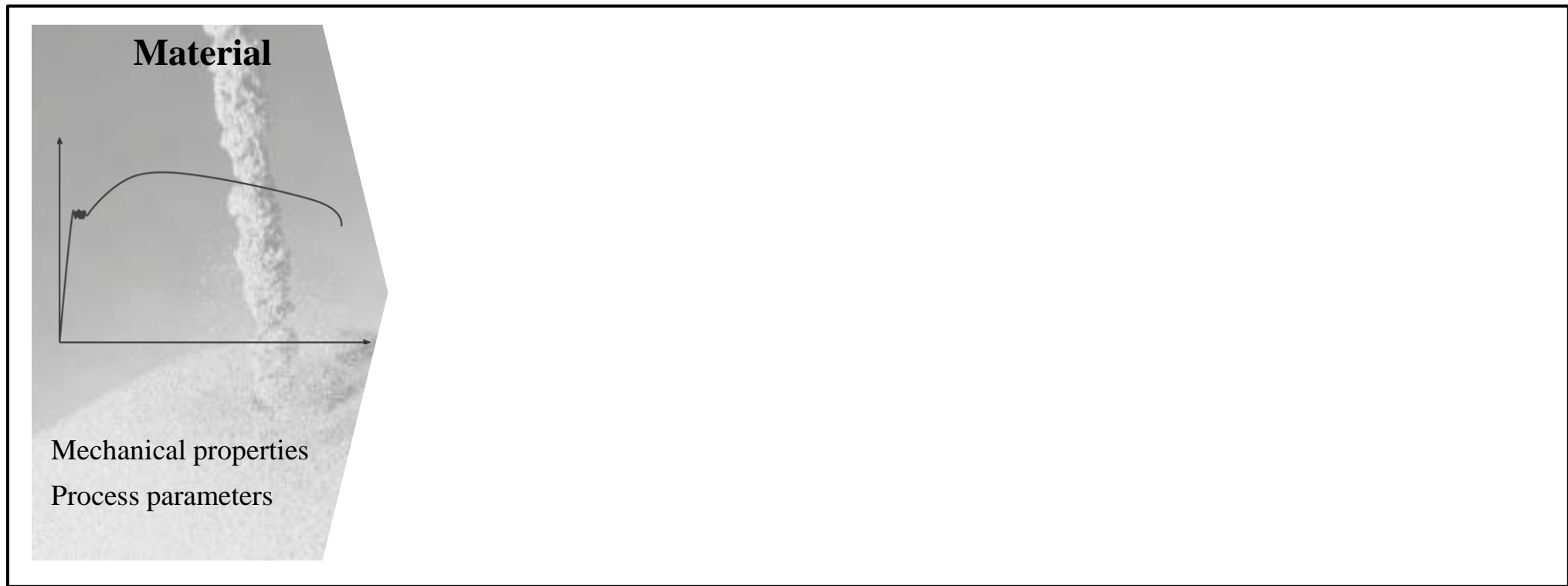


How the LPBF cylinder head is generated



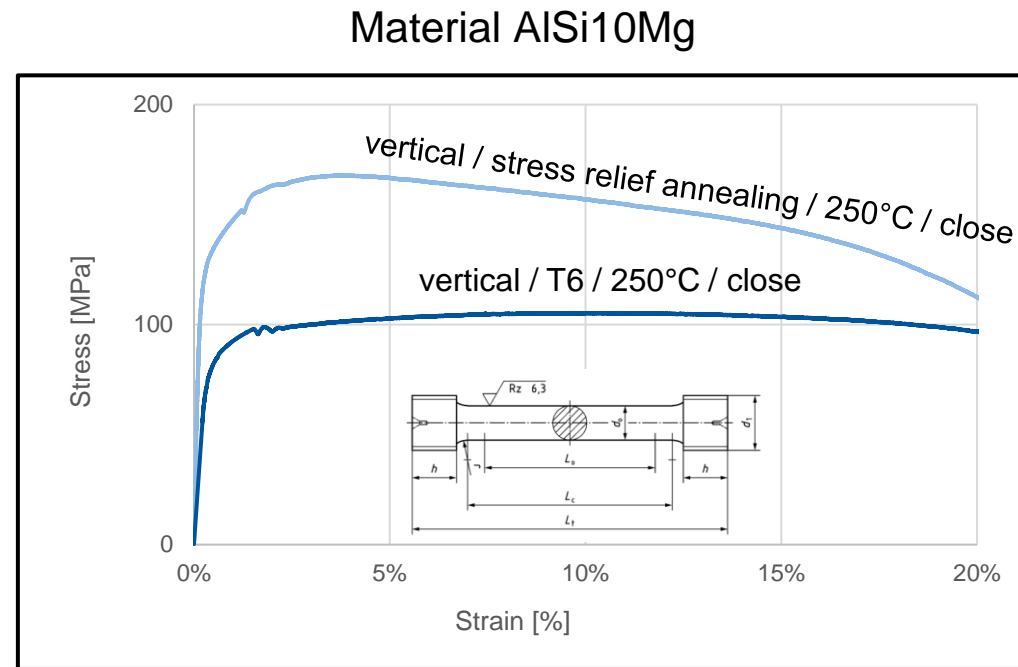
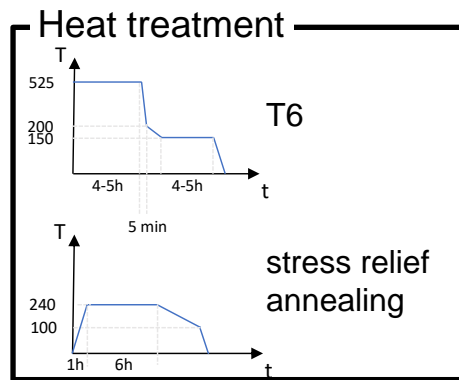
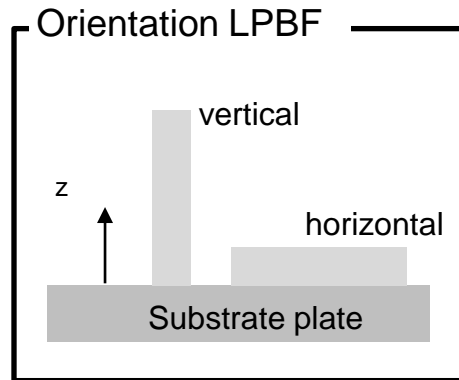


How the LPBF cylinder head is generated

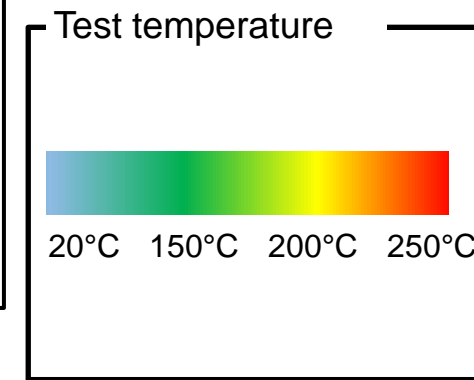
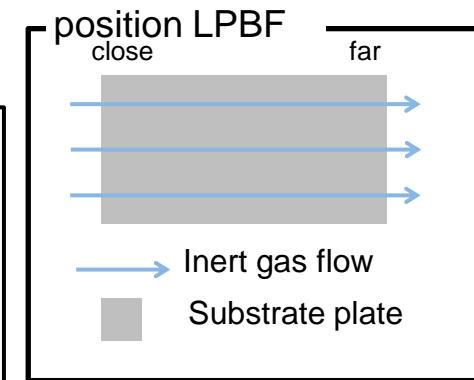




New manufacturing technology results in new material properties



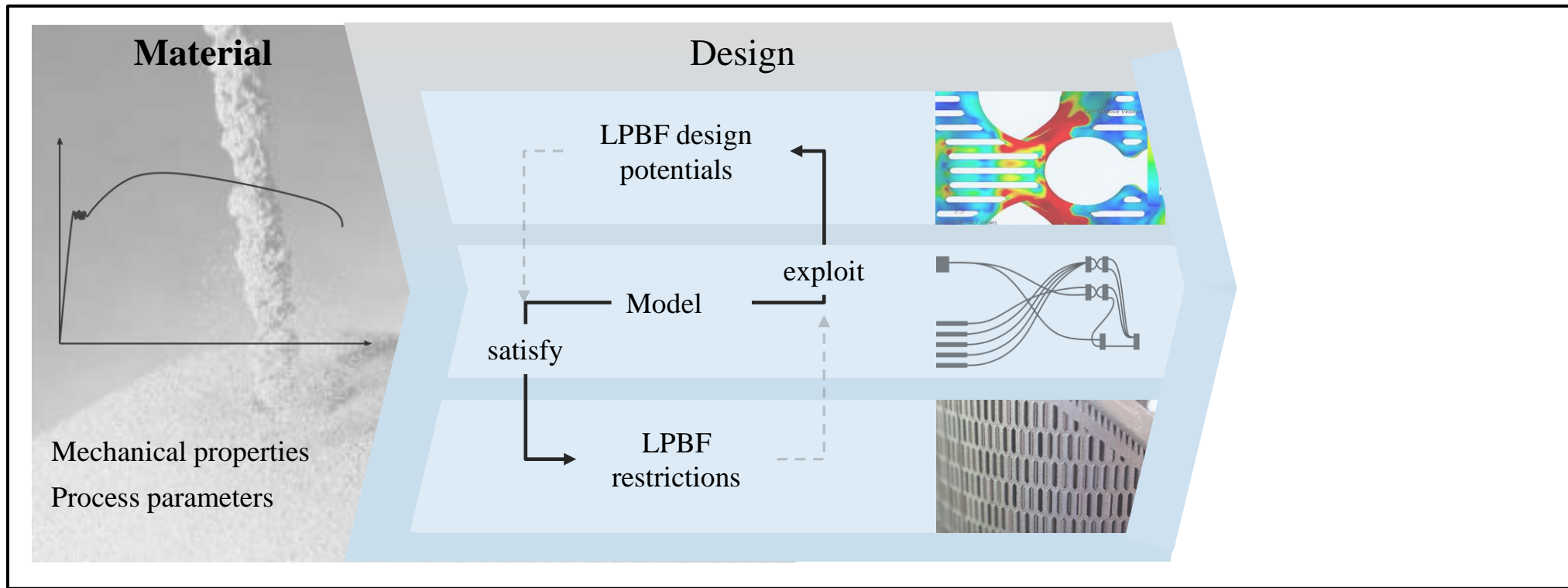
Sample geometry B8x40 DIN50125



Approach



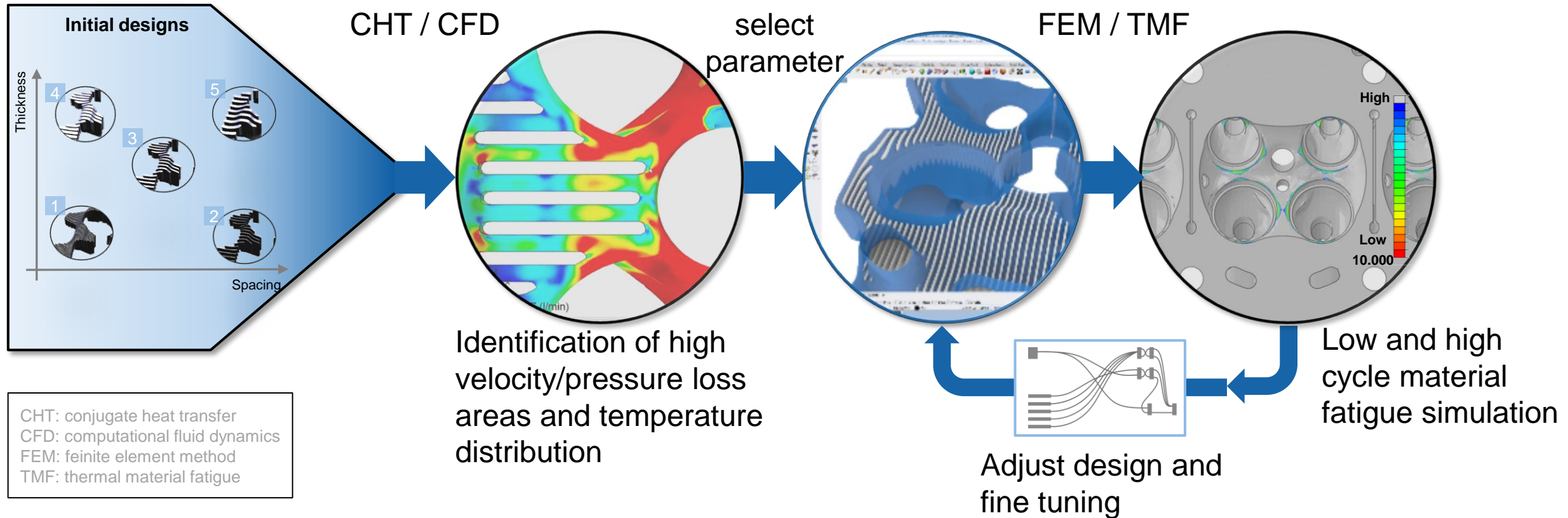
How the LPBF cylinder head is generated





Algorithmic model enables efficient iterative design process

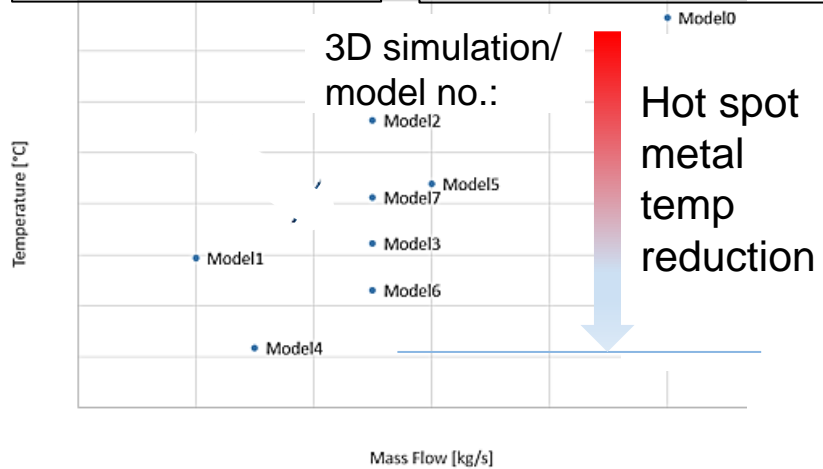
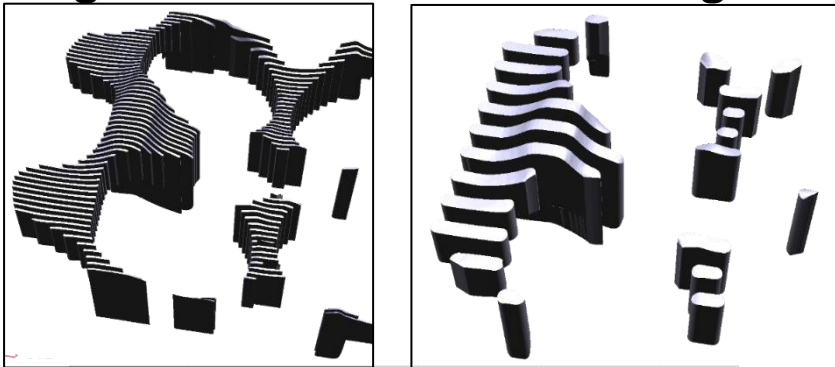
- Iterative approach simulation/adjusting cooling structure design for water jacket until requirements are met





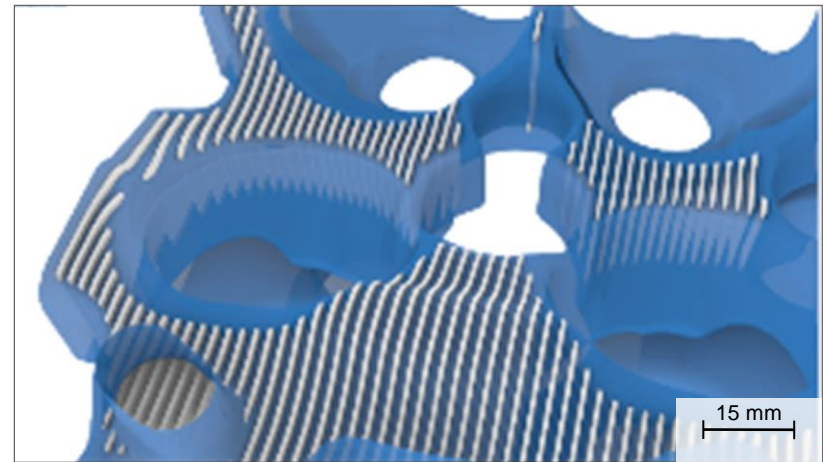
Initial Design

Design variation for ideal cooling



Integration in final cylinder head

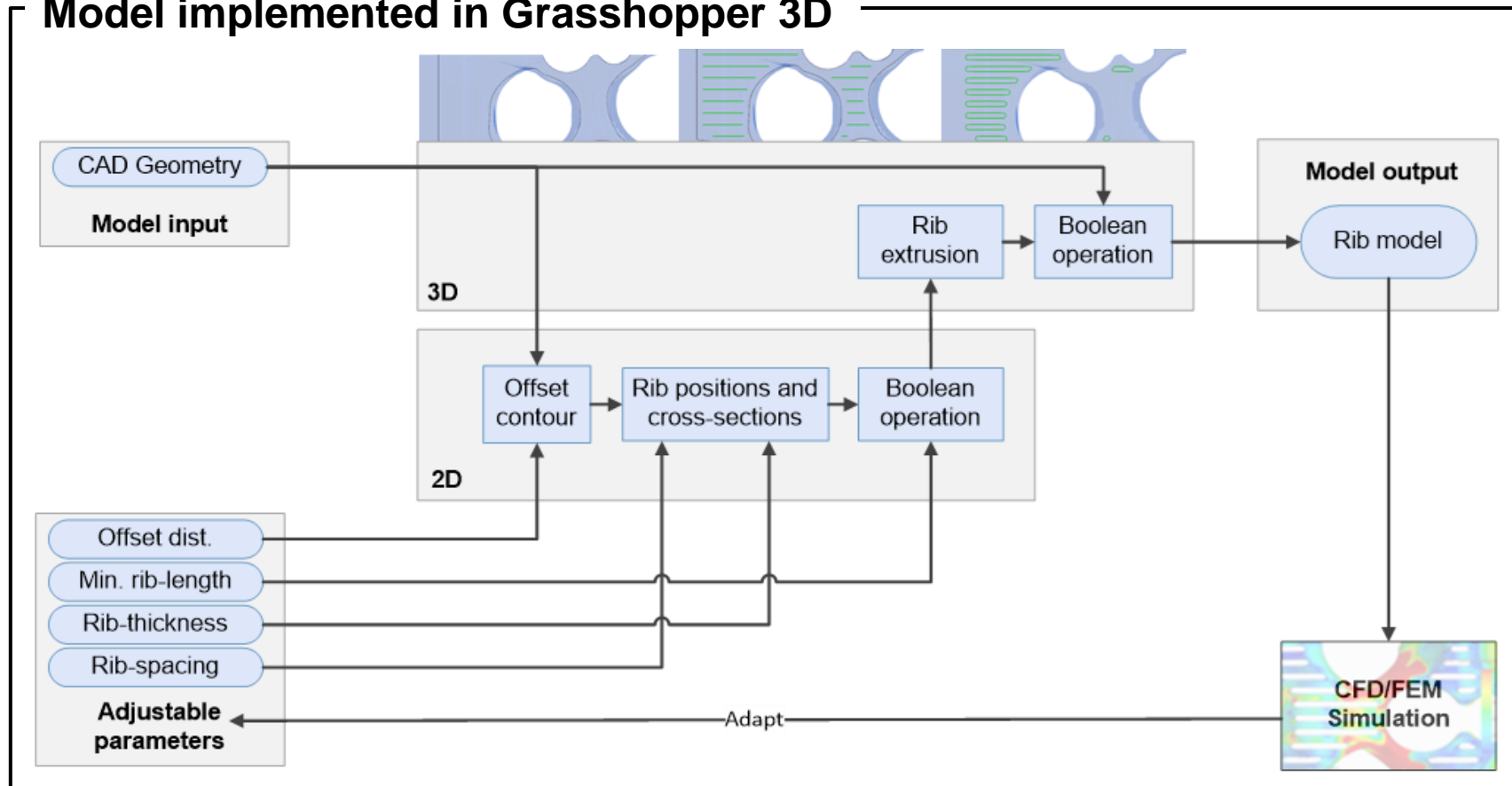
- Final parameter are integrated in cylinder head water jacket and verified by simulation
- Generative design model





Algorithmic model enables efficient iterative design process

Model implemented in Grasshopper 3D

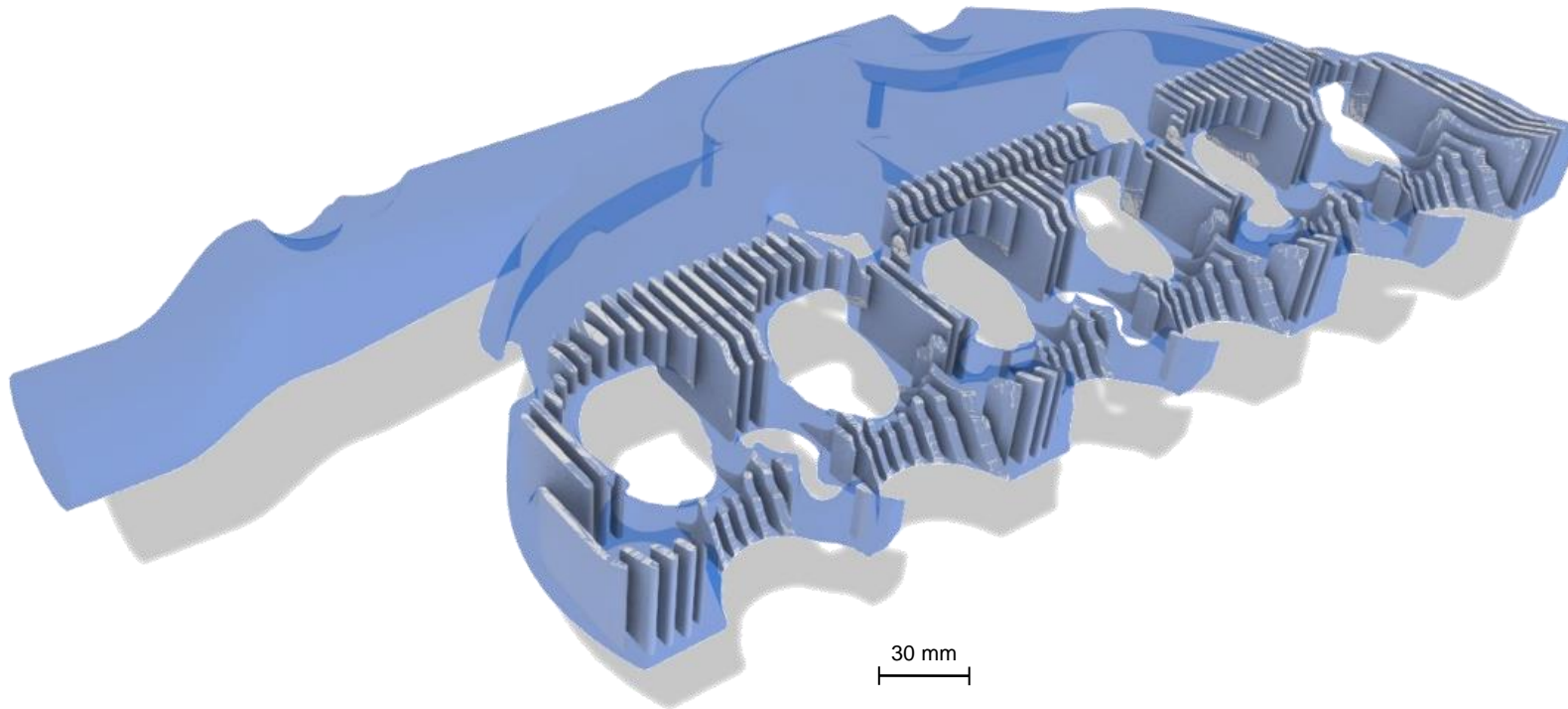


- Fast generation of differently parametrized structures
- Parametric visual programming environment of Grasshopper 3D
- CAD-file of the cylinder head serves as the input for the generative model



Final Cooling Structure Design: Potential

Cooling structures integrated in water jacket



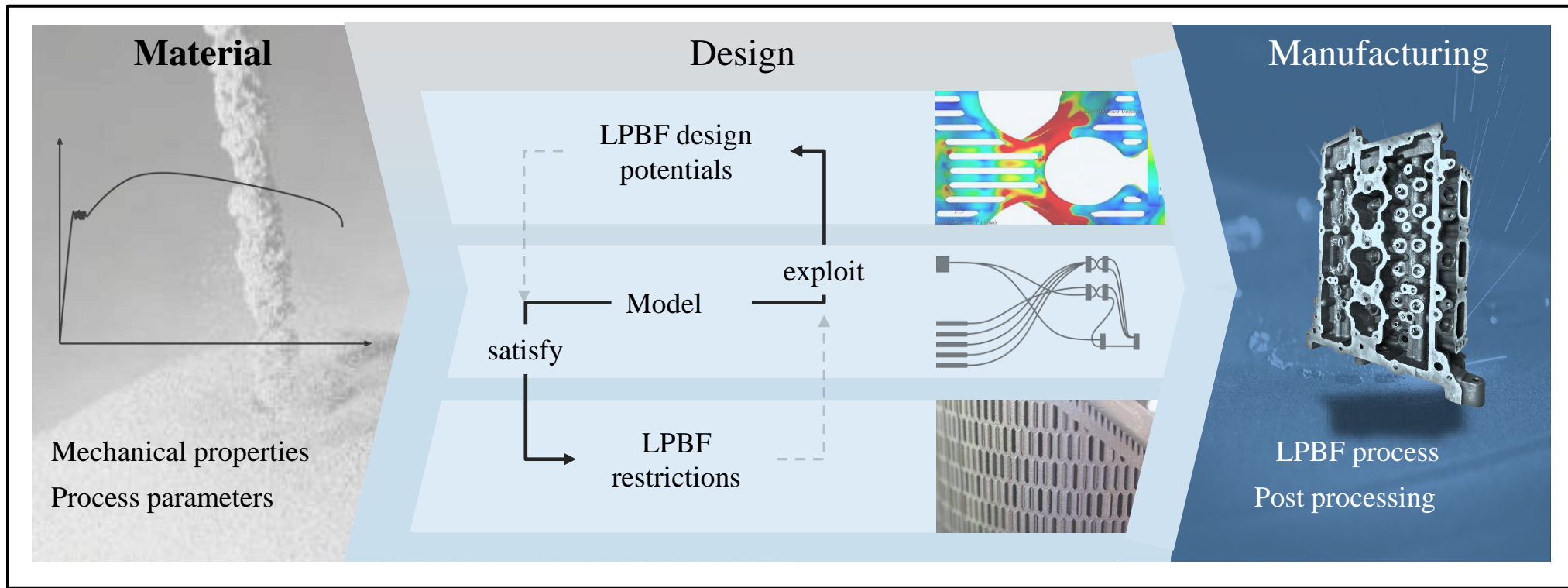
Additional features for final cylinder head design:

- Metal temp instrumentation
- Reduction of combustion chamber roof thickness
- Additional cooling features

Approach



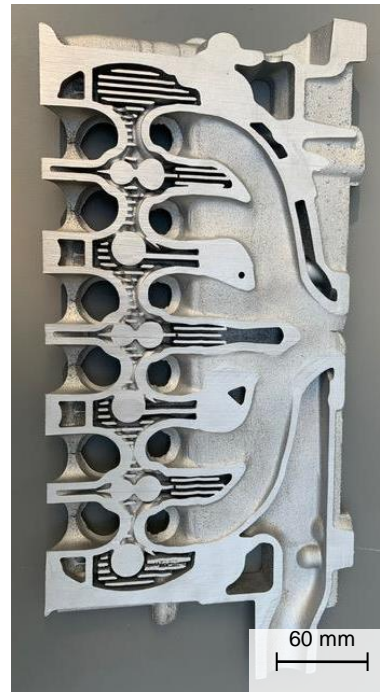
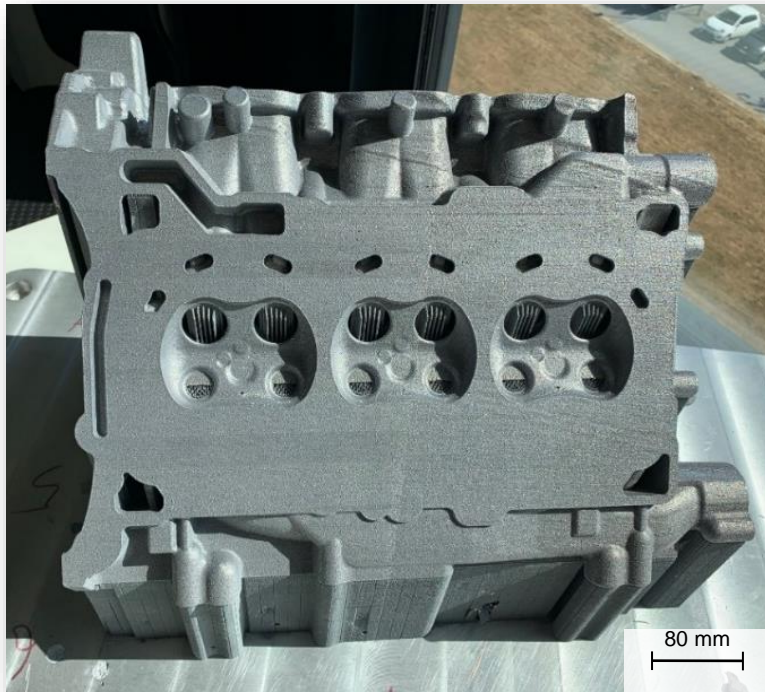
How the LPBF cylinder head is generated





Successful production and post-processing for test under real conditions

Cooling structures integrated in water jacket



- Cylinder head is manufactured on a X Line 2000 R system
- Build time around 12 days
- Build high 299,25 mm
- Preheating 200°C (scaled build data)



Ready to Test Cylinder Head:

- Tests on a 1.5l I3 GDTI engine dyno test bench show a reduction in coolant temperature of over 30 K
- Successful manufacturing and postprocessing of cylinder head with internal cooling structures
- In the first step, a specific feature, the water jacket, is considered and optimized to improve the function
 - In order to exploit the full potential of the LPBF for this component, a complete redesign is necessary.
 - Further functional improvement (lightweight, combustion air)
 - Reduce number of support structures

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