A06

Laser Powder Bed Fusion (LPBF) of Steel Elements for Construction – Basics of Design and Mechanical Resilience

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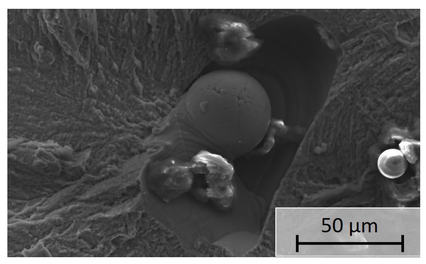
Summary

The objective of this project is to explore and evaluate the factors influencing the manufacturing of safe and durable structural steel elements by LPBF. Thereby, the LPBF process, the post treatment and the geometrical aspects in terms of microstructure and mechanical properties will be investigated and correlations determined. In this first funding period it is focused on analysing small scale specimens as well as on complex facade elements with multiaxial stress states. Based on the results, a first methodology for a qualified AM design of safe and durable structural steel elements will be derived.

Preliminary Work

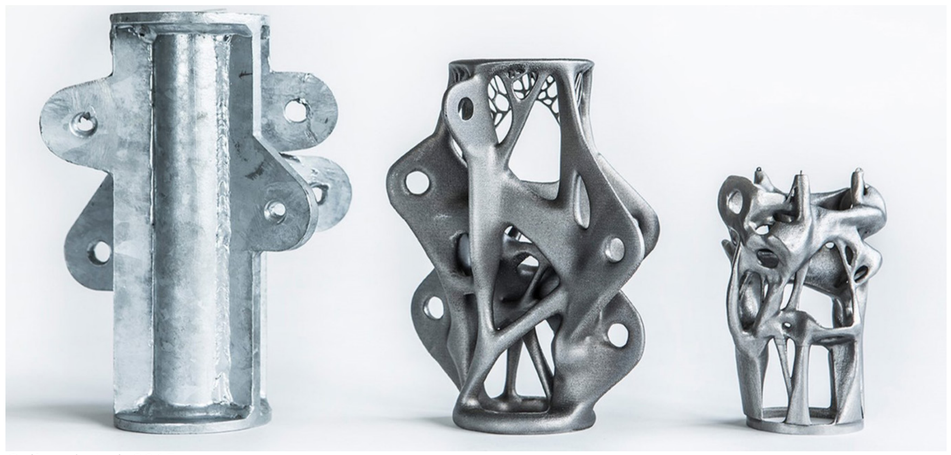
- Thermographic process monitoring of LPBF manufactured parts (iwb)
- Residual stress measurement of LPBF manufactured elements by using the neutron diffraction method as well as the drill hole method (iwb)
- Effect of geometry on the cooling rate of LPBF manufactured 316L (iwb&MB) – **Pre-study for TRR277**
- Mechanical testing (static and cyclic) as well as metallurgical analysis (microstructure and fracture surface) of LPBF manufactured parts with varying gas mixtures (MB)
- Development of topology optimised and LPBF manufactured tensegrity node for the Deutsches Museum (MB)
- Derivation of design concepts and guidelines for steel and aluminium structures (MB)



The SEM image shows a lack of fusion pore on a fractural surface from a fatigue sample. The image has been taken near the surface. (MB)

Research Question

- State of research shows, that no reliable prediction and reproducibility of macroscopic and mechanical properties of LPBF manufactured steel elements is possible
- Process monitoring through thermography, mechanical testing, microstructural analysis, heat treatment as well as the influence of laser parameters on mechanical properties have been investigated partially, but separately from each other
- No correlation between these research areas has been conducted yet
- High demand for LPBF recommendations for a safe and reliable production and design of LPBF steel elements



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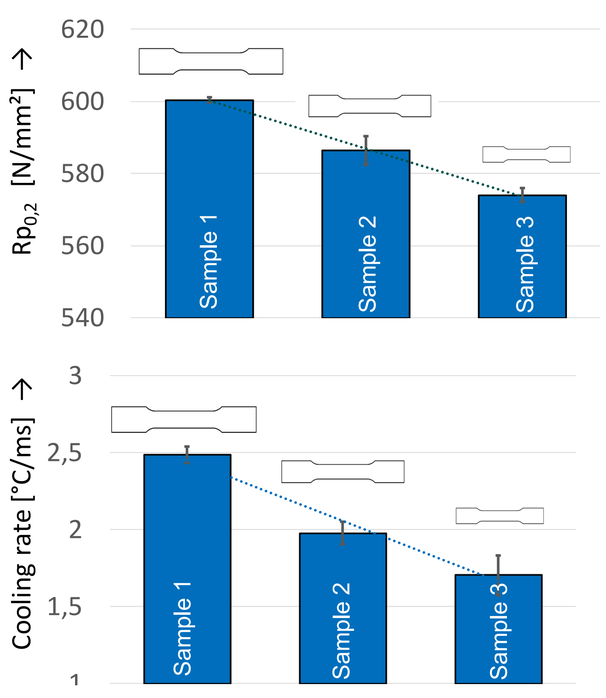
Development and realisation of a topology optimised LPBF-tensegrity node. It shows the process from the initial, conventional design over a first topology optimised structure to a final structure.

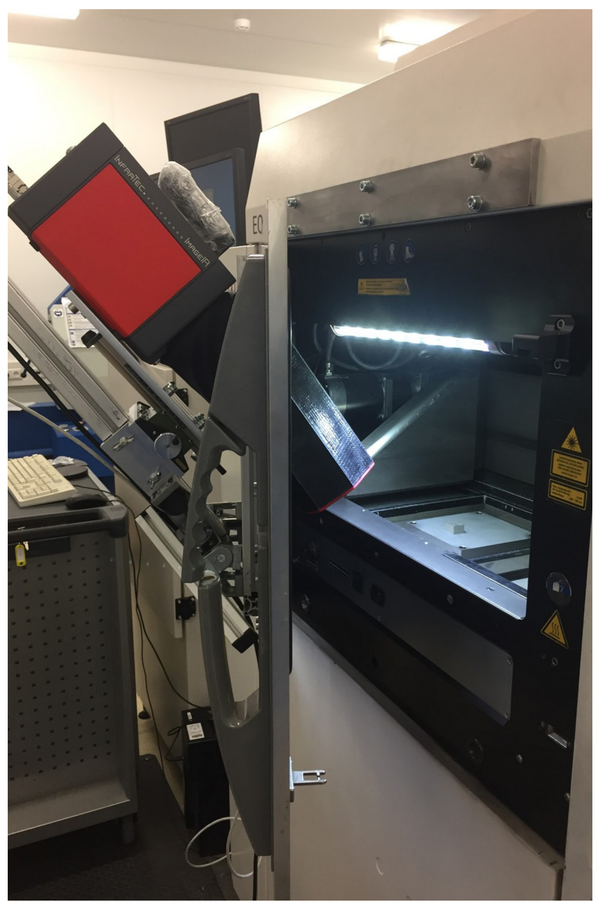
Note: Due to insufficient fatigue resistance it has not been integrated into real structures.

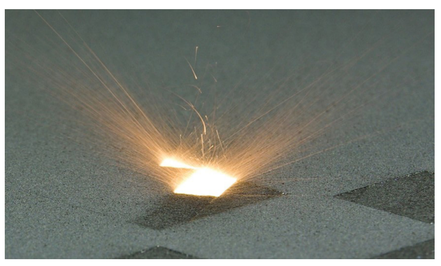
Methods

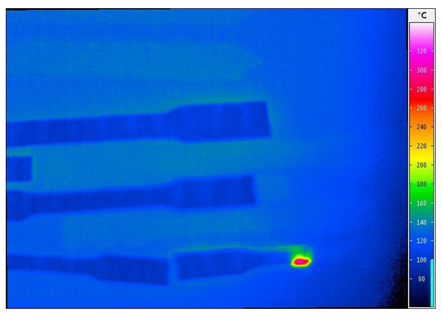
- Manufacturing of all steel specimens and elements will be done on the EOS M270 and EOS M400-1 LPBF machines (iwb).
- Monitoring of the cooling rates will be done by high-speed thermo-graphic imaging. Therefore, the door of the process chamber has to be further adapted (iwb).
- Stress relief annealing and hot isostatic pressing will be done at MB.
- Mechanical testing will be performed at the MB facilities (REL 2041, Instron 8032, Zwick 600, REL 10, EVO 1600 etc.).
- Metallurgical analysis will be conducted by MB and includes SEM, EDX, XRD as well as EBSD.



Pre-study: Correlation of different tensile sample sizes between cooling rate and yield strength. Possibly caused by different grain growth rate. (MB)







Left: modified chamber door of the EOS M270 machine with a high-speed thermographic imaging system.
Top: process and thermo-graphic image of the LPBF process during the manufacturing of tensile samples. (iwb)