Characterization and Comparison of Mechanical Properties of SLM Materials with Regard to Process Cycle Time Improvement

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Since a high productivity is a crucial criterion for the use of a specific manufacturing process, it is the goal of this project to find optimal exposure parameters of the SLM process with regard to required cycle time and component quality. In this study design of experiments is used as a method to characterize the influencing factors and their influence on specific target values. The best parameter set is used to produce test specimens for mechanical testing. To perform analyses of the build-up rate, a real-time data collection software was developed within this project.

Design of Experiments

The sensitivity analysis as a first major issue within this project aims at shedding light regarding the influence of exposure parameters on the mechanical properties such as

- Porosity
- Material density
- Hardness

of SLM manufactured stainless steel 316L, cf. Figure 1a. In order to obtain a deeper understanding regarding the effects of exposure parameters, design of experiments (DoE) was used to allow for a systematic approach concerning this multi-parameter problem. Based on the findings of this process parameter study samples for mechanical analyses and build-up rate studies are produced with a set of process parameters that results in optimal material condition towards porosity, material density and hardness.

SLM parts under monotonic and cyclic loading

This work package deals with the characterization and comparison of SLM components regarding its mechanical properties such as:

- Monotonic properties
  - Tensile strength
  - Yield strength
  - Elongation at break
- Cyclic properties
  - fatigue behavior
  - crack growth performance

Test samples for this investigation were manufactured on the SLM 250^HL and SLM 280^HL using optimized set of process parameters.

As an example, Figure 2a shows mono-

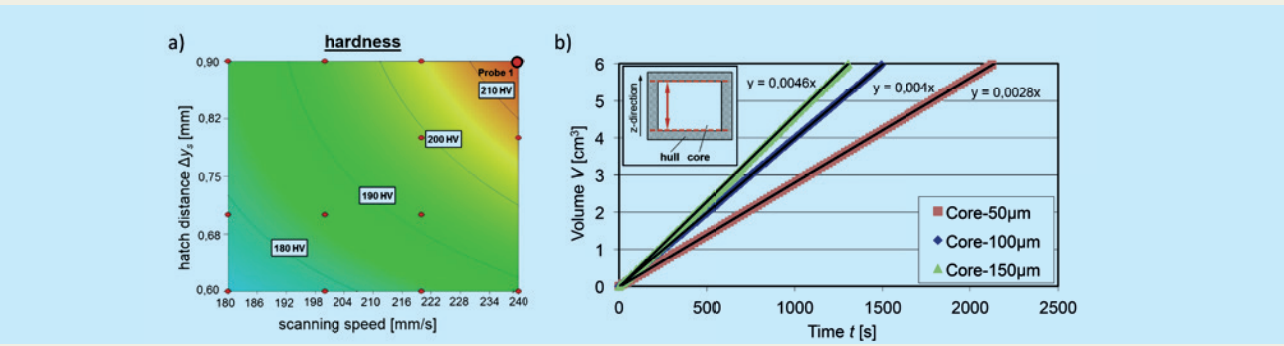

Figure 1: Results obtained by Design of Experiments (a) and the output of the real build-up rate study (b)

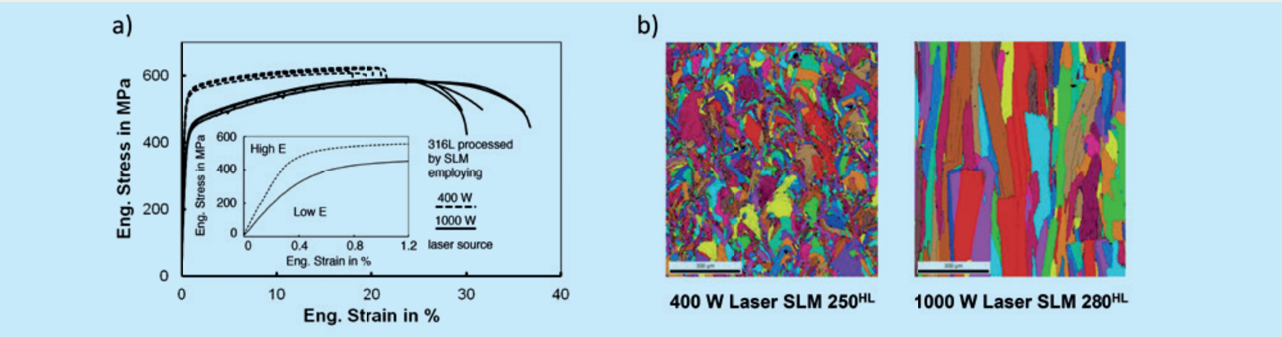

Figure 2: Monotonic stress-strain curves for the SLM processed 316L (a) and EBSD maps for 316L obtained by 400 W Laser (SLM 250^{HL}) and 1000 Watt Laser (SLM 280^{HL}) (b)ments (a) and the output of the real build-up rate study (b)

tonic stress-strain curves for 316L processed on SLM 250^{HL} and SLM 280^{HL}. It can be seen, that both processes result in fundamentally different behaviour under monotonic loading. By analyzing the microstructure in Figure 2b, the differences in strength and ductility can be explained according to the hall-petch relationship. It can be seen, that the evolution of the local microstructure is strongly dependent on the exposure parameters. While the conventional 400 W laser results in a weakly textured fine grain structure, the 1000 W laser causes significantly larger grains strongly elongated in build direction.

Similar to the monotonic properties, also in case of cyclic loading different behaviour for both laser systems are established. Here the material performance is affected in a negative way by increased laser power and consequently increased build-up rate.

Determination and analysis of the real build-up rate

This work package is focussed on the comparison between SLM 250^{HL} and SLM 280^{HL} with respect to the build-up rate and the resulting component quality. Therefore, cubic test samples were created in order to measure the process cycle time of both SLM systems, cf. Figure 1(b). Three layer thicknesses (50µm, 100µm and 150µm) were considered in this study. In order to obtain detailed values for exposure and recoating times, a real-time data collecting script was developed which is able to scan the SLM-log-files for the time data required for recoating and exposuring in each layer and to sum them up. Recent investigations have shown the possibility to increase the build-up rate by about 39% using the SLM 280^{HL} compared to the conventional SLM-250^{HL} system.

Application of findings

Finally, all project results regarding an optimal balance between build-up rate and component quality was transferred to a real component in order to demonstrate the performance of this innovative AM technology.

Project responsibility

This research project is being processed by the two departments “Automotive Lightweight Construction” and “Institute of Applied Mechanics”.