Laser powder bed fusion of 316L stainless steel - Microstructure and mechanical properties as a function of process parameters, design and productivity

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One of the most common additive manufacturing techniques for fabricating metallic components is laser powder bed fusion, which has demonstrated great potential in fabricating parts with properties exceeding the properties achieved via conventional methods. To fully utilize the process's potential, a more profound understanding of the microstructure and properties of the laser powder bed fusion processed material is required. This thesis aims to provide new insights into how the microstructure, mechanical properties and productivity are affected by part design and process parameters. The thesis is framed around a detailed investigation of the parts produced in stainless steel 316L.
The provided results reveal that producing parts with standard process parameters leads to near-full density with excellent tensile properties and a microstructure consisting of large elongated grains with predominant <101> orientation characterized by a fine submicron cellular structure. It was demonstrated that part thickness does not influence component density, but the grain morphology and texture are affected close to the part edges. Reducing the part thickness to less than 0.5 mm reduced the predominant texture and reducing the part thickness to less than 1 mm reduced the yield strength.

Altering the process parameters affected the crystallographic orientation, grain size and cell size and thus the tensile properties. Minor effects of processing gas composition (Ar, N2 or He) on the chemical composition, microstructure, tensile strength and hardness was detected.
In addition, it was revealed that a 20% faster build time could be achieved without compromising the static properties by adjusting the scan speed and hatch distance. Increasing the layer thickness to 80 μm allowed for shortening the build time by a factor of four but with a 14% reduction in yield strength and 17% reduction in ductility.

The findings provided in this thesis serve as a basis for the development of rules for part design and qualification of mechanical properties for manufacturing parts with fine design features via laser powder bed fusion. The results emphasize the importance of the part design on the microstructure and the properties of the produced component. In addition, the presented results emphasize the potential for significant improvement in build speed in the laser powder bed fusion process, exemplified for 316L.