HÖGSKOLAN VÄST

Laser Powder Bed Fusion of Ti-6Al-4V for Industrial Applications:

Balancing Productivity and Mechanical Properties

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AKADEMISK AVHANDLING

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Abstract

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Additive Manufacturing has transformed the production of metallic components by enabling complex geometries to be manufactured directly from digital models while reducing material waste and shortening the design-to-manufacture route. Among metal AM technologies, laser powder bed fusion (PBF-LB) has gained considerable industrial interest, particularly in the biomedical, automotive and aerospace sectors. Despite these advantages, wider industrial adoption remains constrained by relatively low build rates, feedstock optimisation costs and the need to consistently achieve the material quality required for structural applications by adding post processing.

This thesis investigates strategies for increasing the productivity of PBF-LB processing of Ti-6Al-4V while maintaining suitable mechanical properties. A wide powder particle size distribution of 15-90 µm was combined with an increased layer thickness of 70 µm, and a specific processing window was established by evaluating the effects of laser power, scanning speed and hatch distance on melt pool behaviour, consolidation and defect formation. The results show that the wider powder distribution can be successfully processed at increased layer thickness, provided that the process parameters are appropriately adapted.

Two representative processing strategies were subsequently investigated: a minimal porosity and a high productivity condition. The latter showed reduced ductility and impact toughness in the as-built condition due to lack-of-fusion defects. Hot Isostatic Pressing (HIP) was therefore investigated both as a consolidation method and as a means of tailoring the microstructure. Sub-β transus HIP effectively consolidated internal defects while retaining a comparatively refined microstructure and promoting high ductility. HIP above the β transus produced coarser prior-β grains and larger α colonies, improving impact toughness and fatigue crack growth resistance but reducing tensile strength and resistance to fatigue crack initiation. These findings show that the as-built condition affects not only defect formation but also the microstructure developed during subsequent HIP treatment.

Finally, programmable laser beam shaping was investigated as an additional tool to vary the thermal behaviour during processing.

Overall, the thesis demonstrates that increased PBF-LB productivity can be achieved through the combined use of wider powder particle size distributions, increased layer thickness, adapted process parameters and targeted post processing. The results highlight the need to consider productivity, defect content, microstructure and mechanical performance as an integrated manufacturing chain tailored to the requirements of the intended application.