Doctoral Dissertation
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# Optimization of additive manufacturing processes for copper and its alloys

By

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# Summary


In recent times, the utilization of additive manufacturing technologies has risen to prominence as a revolutionary method for fabricating metallic components, presenting unmatched design freedom and efficiency. Among these technologies, powder bed fusion methods stand out as particularly compelling and extensively researched. However, a notable limitation of these technologies arises from the restricted availability of commercial alloys, primarily tailored for conventional casting, which poses challenges for seamless adaptation to these groundbreaking processes. Notably, pure copper and copper alloys present a significant challenge when processed using powder bed technologies due to their inherent reflectivity to optical power sources such as lasers. This thesis explores the processing of pure copper and the CuNi2SiCr alloy via Electron Beam Powder Bed Fusion (EB-PBF) and Laser Powder Bed Fusion (L-PBF) methods, optimizing the process parameters and subsequently investigating their microstructural evolution, mechanical properties, and post-processing heat treatment optimization.

Initially, the processability of pure copper through the EB-PBF process was investigated. After the process parameters optimization, full dense samples were successfully achieved. Following this, comprehensive characterization of the produced samples was conducted, focusing on microstructural analysis, phase composition, and mechanical properties evaluation.

Subsequently, the thesis shifted its focus to the CuNi2SiCr alloy, investigating its processability across various L-PBF machines. Specifically, three machines were employed for this investigation: two equipped with a red laser source (with low and medium power sources), and one equipped with a green laser source. The optimization of process parameters was conducted across all machines, yielding varying outcomes. Samples produced using the low-power red laser exhibited incomplete densification, attributed to insufficient laser power. Conversely, the medium-power red laser and green laser machines facilitated the production of fully dense samples. Afterwards, all optimized samples underwent comprehensive characterization resulting in very similar microstructure, depending on the specification of the machine, and comparable mechanical properties.

Furthermore, two distinct post-processing heat treatments tailored for the precipitation hardening of the CuNi2SiCr alloy, fabricated via the L-PBF process, were optimized. The first heat treatment,

involving direct aging, yielded comparable performance to the second, which comprised a short T6 heat treatment.

Moreover, the feasibility of employing the hot isostatic pressing (HIP) process to densify the incompletely dense samples was evaluated. Concurrently, this process served as the initial step of the optimized short T6 heat treatment. However, it was observed that the HIP process was unable to achieve complete densification within the short timeframe required for the short T6 treatment. Nevertheless, it was determined that extending the duration of the HIP process could potentially lead to the complete densification of the samples.

Finally, suggestions for future development and analyses were proposed.