Summary - Laser Powder Bed Fusion of AlSi10Mg+4Cu and AlSi10Mg alloys

Laser Powder Bed Fusion (LPBF) is one of the most used additive manufacturing techniques, which enables the production of metallic parts by selectively melting consecutive layers of powder according to 3D model data. Apart from its inherent advantages related to the high design freedom, customized manufacturing and limited material waste, LPBF also has several barriers that prevent this technique from entirely succeeding in the manufacturing market. On the one hand, the rapid solidification induced by laser heating opens the possibility to develop new alloys specifically designed for LPBF with performances superior to the conventional counterparts. Nevertheless, today, only a limited palette of metallic alloys is available in the marketplace. On the other hand, the low productivity of LPBF results in the high production cost of additively manufactured parts. In particular, this limited productivity is often related to the small size of a producible component. Therefore, the overall purpose of the thesis is to help overcome the above mentioned LPBF barriers.

The first study of this thesis reports the experimental results on a novel AlSi10Mg+4Cu alloy processed by LPBF. In this work, 4 wt.% of Cu powder was mixed with a pre-alloyed AlSi10Mg powder to improve hardness and strength of AlSi10Mg. Afterward, AlSi10Mg+4Cu alloy was directly synthesized in-situ by exploiting the intense laser energy during LPBF manufacturing. Single scan tracks were then used as a tool to quickly evaluate the alloy processability. Once defined the suitable process window by analyzing scan tracks characteristics, the chemical composition, the microstructure, and the mechanical properties of as-built and heat-treated samples were investigated. A T5 protocol was used to heat-treat as-built samples with the purpose of fully exploiting the alloy precipitation potential generated upon the rapid cooling.

Experimental results showed that AlSi10Mg+4Cu alloy was successfully consolidated by LPBF, exhibiting a densification level up to 99.16 % after the process parameters optimization. Moreover, the overall chemical composition of the printed alloy reflected the theoretical one thanks to the mixing effect of the local convective flows arising during melting. However, local segregations of Cu were found owing to the different physical properties of the starting powders creating local inhomogeneities, which in turn resulted in localized hardness peaks. Generally speaking, the addition of Cu was effective in improving the hardness of AlSi10Mg. This was mainly due to the enhanced contribution of super-saturated solid solution and precipitation strengthening mechanisms to the total strength of the alloy. The microstructure morphology of as-built specimens revealed the presence of fine α-Al cells surrounded by a dual eutectic formed by Si and ϑ-Al2Cu phases. Direct aging enabled the solutes diffusion and a progressive hardening without affecting the fineness of the Al-Si/Al2Cu eutectic network. The maximum hardness increment was achieved upon 1 h at 175 °C, and the corresponding microstructure was constituted by a mix of 〖θ^''/θ〗 ^'+θ-Al2Cu precipitates and Si phase. As for the hardness, as-built and directly aged tensile samples returned superior yield and ultimate tensile strength values compared to AlSi10Mg counterparts. Finally, the fracture mechanism of AlSi10Mg+4Cu was characterized by ductile-brittle behavior.

The second study of the thesis aimed at solving the issues related to the production of large AlSi10Mg components by adopting the heated building platform strategy. Two main aspects were tackled. On the one side, the inevitable presence of internal residual stresses that can cause the job failure during long printing time and, on the other side, the in-situ aging of the processed alloy above the heated platform. To this end, the platform temperatures preventing cracks and distortions were firstly determined. Then, the in-situ aging behavior was investigated for samples processed under various platform temperatures and holding times. Our results revealed that the platform temperatures of 150 and 200 °C can effectively prevent cracks and

minimize distortions. Besides, using 150 °C, AlSi10Mg samples can reach the peak hardness with a holding time less than 13 h. In comparison, samples produced with a holding time longer than 13 h at 150 and 200 °C showed an obvious over-aging response and, thus, lower hardness. However, such hardness impoverishment was recovered by using a T6-like heat-treatment.