Abstract

Additive Manufacturing (AM) technologies have disrupted the production paradigm over the last ten years. Furthermore, this trend seems to be continuously growing and will lead AM to expand in the coming decades. Complexity for free concept, high material yield and high mechanical performances are counterbalanced by low production rate and limited productive volumes, especially for the most used metal AM production technique: Laser Powder Bed Fusion (LPBF). Moreover, different boundary conditions require diverse material selection while a restricted materials palette is currently available. Material development for LPBF powder production needs a high cost and a tremendous amount of infrastructure. Gas Atomization (GA) is the most critical and widespread LPBF industrial powder production technology. Powder characteristics imposed by LPBF (shape, dimension, chemical and physical features) can be obtained only by GA production. However, GA plants are costly and difficult for researchers and academics to access. The GA and LPBF availability at Politecnico di Torino allowed us to overcome these technological limits. Thus, the LPBF production line has been studied since 2019 regarding non-commercial Al alloys composition development.

The first part of this thesis is focused on the GA plant installed in Alessandria. After a brief introduction to AM, LPBF and powder requirements, GA is described as AM powder production process. GA process parameters and theory were described to understand the process deeply. AISI 304L was chosen as benchmark product material for its low presence in LPBF scientific literature. 304L Powders were produced by GA using several atomization pressures. Chemical, physical and rheological tests assessed the atomization pressure effect on produced powders.

Moreover, produced powders' properties were compared to commercial products. 304L powders' feasibility for LPBF was then assessed. Single Scan Track (SST) approach was performed to identify a process parameter window for Concept Laser Mlab Cusing R.

An automated image analysis algorithm developed by our research group was used to recognize possible process parameters by on-top SSTs images. LPBF then produced 304L massive samples. The layer thickness effect was investigated concerning sample relative density. Finally, LPBFed sample properties were compared with traditional forming techniques samples ones.

Once the GA plant was tested and powders characteristics assessed, new Al alloy chemical compositions were developed. Firstly, commercial AlSi10Mg massive samples were produced and characterized. The scanning strategy effect on sample relative density was studied. AlSi10Mg was considered a reference material in our alloy design. AlSi10Mg and AISI 304L were mixed in several proportions to obtain two new Al-Fe rich alloys. AlSi8Fe9Cr2Ni and AlSi8Fe18Cr5Ni3 were produced using 1:4 and 1:8 304L/AlSi10Mg weight ratios, respectively. 304L was added both for Fe, Cr and Ni content. All these elements are used in rapidly solidified Al alloys for high-temperature strengthening. Fe and Ni precipitate in high-temperature stable phases, while Cr is mainly used to

modify precipitation kinetics. 304L got a higher melting temperature than AlSi10Mg. When alloys are mixed, melting temperature varies as a function of the element composition. Consequently, volatile element content can be reduced in the melt. For this reason, alloys with very different melting temperatures can be atomized however the segregation effect must be checked. The atomization step was then performed avoiding chemical impurities and modification. After powder production, particles were characterized chemically and physically. Massive sample production was carried out on alloys while only AlSi8Fe9Cr2Ni was LPBF produced. Cracks and pores were evident in this alloy. LPBF feasibility was then improved by μ-TiB2 mechanical mixing to AlSi8Fe9Cr2Ni alloys. More than 99% of relative density was finally obtained. The first approach in GA alloy design was demonstrated with a new Al-Fe alloy composition.