Abstract

Additive Manufacturing (AM) is a relatively new technology that allows the production of components and parts, saving raw materials, costs, and energy. Since its invention, AM has found widespread applications in sectors such as aerospace, automotive, biomedical, and all those fields where great precision is required in the manufacturing of components.

Considering the AM technologies for metallic materials, one of the most widely used is represented by the Powder Bed Fusion (PBF). Under the classification of the PBF process, there are two technologies: Laser Powder Bed Fusion (L-PBF) and Electron Beam Powder Bed Fusion (EB-PBF). Specifically, the work carried out in this thesis was to study and understand in detail the potential of the EB-PBF technology applied to different metallic materials.

The EB-PBF process is characterized by two distinctive aspects: the presence of an electron beam as the power source and a vacuum environment during the printing process. The electron beam allows to reach high power and temperature levels during the printing process, making the EB-PBF recommended for materials with very high melting points or high brittle to ductile transition temperatures, which are prone to crack formation. For these reasons, the EB-PBF process is perfect for materials such as intermetallics and refractory metals. Moreover, the possibility to have a vacuum environment during the printing process helps to avoid contamination and the oxidation of virgin powders during the process, avoiding further impurities or imperfections in the final bulk samples.

For this thesis work, all the investigated materials were produced with the Freemelt ONE machine, commercialized by Freemelt company since 2019. Three different metallic material systems were analyzed in this thesis: pure molybdenum (Mo), Ti-48Al-2Cr-2Nb (4822), and Mo-16.5Si, two different types of intermetallic compounds.

Pure Mo was chosen for its good mechanical and thermal properties, which make it suitable for all of those applications where it is required to work in extremely high temperature environments. The studies already published in the literature on pure Mo processed by the EB-PBF process are very limited, and so this work aimed to fill some gaps and expand the knowledge on this material in

terms of processability, microstructure, and mechanical performance. The results showed that it is possible to obtain crack-free with a low porosity level samples by using the correct process parameters. Moreover, the bending strength revealed mechanical performance in line or superior to the traditional processed pure Mo. Then the efforts conducted on this study culminated in a publication in an international journal.

The 4822 intermetallic compound, it is widely used for the construction of low-pressure turbines for aircraft engines. This material presents different microstructures strictly dependent on the aluminum (Al) concentration. During the EB-PBF process, due to the high recorded temperatures, there is an evaporation of the Al content in the final bulk samples that leads to a heterogeneous microstructure and mechanical properties. For these reasons, the study of this second material was twofold: on one hand, the process parameters were optimized to reduce the porosities, and on the other, an attempt was made to minimize Al losses.

The Mo-16.5Si alloy is partially composed of molybdenum silicide, a promising class of intermetallic compounds, which could replace nickel-base superalloys for high-temperature applications. Starting from the virgin powders of Mo and silicon (Si), a mechanical mix was prepared and then used during the printing process. The aim of this study was to achieve the chemical reaction inside the Freemelt ONE machine to demonstrate the potential of the EB-PBF process. In fact, this class of materials is prone to cracking due to its intrinsic brittleness. The results showed the success in the in-situ reaction showing that the microstructure consisted of columnar Mo_3Si grains surrounded by small solid solution Mo grains. However, the samples still presented cracks mainly formed along the grain boundaries, especially located at the top and bottom of the samples. The results obtained during this study also led to the submission of a second paper currently under review.