Summary

Aluminium alloys are successfully produced through Laser Powder Bed Fusion, appreciated for their low density and good mechanical performance. However, their behaviour at elevated temperatures, especially in complex lattice structures, remains insufficiently explored, particularly for less conventional alloys, despite the proven success of lattices in heat exchangers and lightweight engines. This PhD project focused on investigating the interplay between heat treatments, microstructure, and mechanical behaviour of aluminium lattice structures.

Two aluminium alloys, Scalmalloy® and AlSi9Cu3(Fe), were investigated: the former is a high-strength alloy known for its excellent strength-to-weight ratio in additive manufacturing, while the latter is widely used for casting of automotive parts but is scarcely studied in additive processes. For AlSi9Cu3(Fe), after assessing conventional heat treatments with focus on machining and corrosion, a broader investigation aimed at improving ductility while maintaining industrial feasibility was conducted. For Scalmalloy®, the study evaluated the influence of process parameters on dimensional accuracy and density of lattice structures, along with the compressive behaviour before and after heat treatment. The impact of varying relative density was also evaluated, comparing the results with the theoretical model. Finally, compressive performance of both alloy lattices at room and elevated temperatures was compared, providing insights into material strengths and limitations for thermally demanding applications.

Investigations on AlSi9Cu3(Fe) produced by Laser Powder Bed Fusion revealed promising results. The as-built microstructure offered high strength but limited ductility. Various heat treatments induced notable microstructural changes that affected the corrosion resistance. Corrosion tests showed the best resistance in the as-built state due to the intact Si network, while heat treatments raised corrosion current densities. Then, further heat treatments aimed at improving ductility were tested in bulk tensile. Treatment at 300 °C for 1 hour offered a strength-ductility balance, while treatment at 400 °C for 1 hour transformed the microstructure, enhancing ductility at the expense of strength.

The research on Scalmalloy® provided insights into process parameter optimisation and mechanical properties enhancement in lattices produced by Laser Powder Bed Fusion. Using a factorial design and statistical analysis, the study showed that scan speed, hatch distance, and downskin power significantly affect porosity and dimensional accuracy, confirming them as key quality drivers. Heat treatment increased yield strength and shifted deformation from bending- to stretch-dominated, highlighting the role of microstructural evolution. A compression comparison confirmed heat-treated Scalmalloy® as a benchmark for room temperature strength, due to its refined microstructure and effective precipitation. Overall, the findings offer guidelines for optimising processing and expanding Scalmalloy® use in engineering applications where high strength-to-weight ratios are required, especially at room temperature.

Remarkably, under compression at elevated temperatures, as-built AlSi9Cu3(Fe) lattices outperformed Scalmalloy®, showing excellent thermal resistance and mechanical stability. However,

it exhibited catastrophic collapse at room temperature. The 400 °C heat treatment improved ductility and avoided abrupt failure, ensuring consistent performance across temperatures. This positions AlSi9Cu3(Fe) as a cost-effective alternative to Scalmalloy® for thermally demanding applications. These findings underscore the versatility of Laser Powder Bed Fusion and the alloy potential in lightweight structural components, especially in aerospace and automotive sectors, where thermal mechanical reliability is critical.