Study of heat treatments for the Inconel 625 and process optimization for the Inconel 939 produced by Laser Powder Bed Fusion

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Study of heat treatments for the Inconel 625 and process optimization for the Inconel 939 produced by Laser Powder Bed Fusion

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Summary

Among Additive Manufacturing (AM) technologies, Laser Powder Bed Fusion (LPBF) is attracting a lot of interest from both university and industry, thanks to the capability to produce in a single step near net shape components. This possibility is particularly interesting for the production of complex components in alloys which is expensive to process with traditional technologies, such as Ni-based superalloys.

However, the LPBF technology is a relatively new technology, that produces alloys with a really peculiar microstructure thus presenting challenges in the alloys processing as well as up to now a quite limited portfolio of materials for which are already known the process parameters. So the potential of this technology is twofold. On the already processed materials, more knowledge of the process is required, in term of effect of the process parameters, properties of the LPBF produced alloys as well as the effect of the standard or optimized heat treatments. Contemporary there is free space to optimize the process parameters for a great number of new alloys.

In this thesis work, I followed exactly this twofold line.

On one side I focused the attention on the already known Inconel 625 (IN625) produced by LPBF as well as on the other side I started to work by LPBF with the Inconel 939 (IN939).

IN625 is a superalloy that already proved to be very compatible with the LPBF process, thanks to its high weldability, so a lot of studies are already available in the literature. However, the effect of the commonly suggested heat treatments is still not clear, and there is a lack of literature on the oxidation behaviour for the LPBF IN625.

The first part of this thesis is focused on the investigation of as-built LPBF IN625 and the effect on standard annealing treatments on the microstructure and mechanical properties. The results show that the as-built condition possesses an anisotropic grain structure with fine dendrites, segregations and a high Low Angle Grain Boundaries (LAGB) content, that result in high Yield Stress (YS), Ultimate Tensile Strength (UTS) and a marked anisotropy in the mechanical properties.

Appling low temperature annealing temperature causes precipitation and a partial segregation dissolution. Higher annealing temperatures remove the segregation and not carbide phase, and from 1030 °C causes recrystallization. Increase the annealing temperature gradually reduces the LAGB content, reducing YS, UTS and the mechanical anisotropy, improving the elongation.

In the second part, the oxidation performance at 900 °C of the as-built IN625 and the solutionized alloy are evaluated. The chosen temperature is comprised in the application temperature range of this alloy, and produces microstructural changes during the thermal exposure. The results show a superior oxidation resistance for the as-built condition, that develops a compact and continuous oxide layer. The solutionzed alloy inferior resistance is caused by defects in the oxide layer, that reduce the passivating effect and lead to the formation of mixed oxides.

At the end of the thesis, the effect of the process parameters in the production on the Inconel 939 is evaluated. Unlike the IN625, this alloy is prone to cracking during the process due to the presence of γ' formation elements. However, the results show that some parameter combinations allow the production of dense samples with an extremely low cracks content. The resulting microstructure is characterized by elongated grains and a fine dendritic structure, with the presence of nanometric precipitates that play a role in the cracking mechanism.