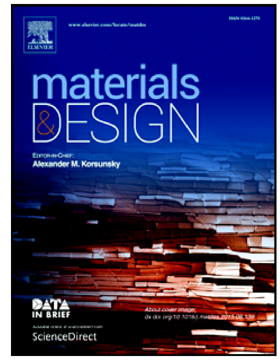

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Impact of heat treatment on mechanical behaviour of Inconel 718 with tailored microstructure processed by selective laser melting

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Abstract

Additive manufacturing (AM) technologies are known to allow the production of parts with an extreme degree of complexity, enabling design and functional part optimization. However, the resulting microstructures and mechanical properties of AM materials are not well understood due to unique and complex thermal cycles observed during processing. This study aims to adjust the microstructure of Inconel 718 specimens produced by selective laser melting (SLM). The microstructural design was achieved through process parameters manipulation and post-process heat treatment. The effects of heat treatment on microstructure, process induced defects, deformation behaviour and failure mechanisms were studied. Directional columnar grained microstructure accompanied by interdendritic Laves phases and carbide particles was observed in as-processed material. Hot isostatic pressing (HIP) improved mechanical properties, which was attributed to dissolution of undesirable Laves and δ-phase as well as pore closure. All investigated samples maintained their intended tailored microstructural build up with distinct differences in mechanical properties. The results presented in this study show the capability of the SLM process to produce parts with mechanical properties better than conventional Inconel material. The microstructural design demonstrated here can be exploited in AM fabrication of complex components requiring challenging high-temperature mechanical performance.

Keywords Additive manufacturing; Ni-base alloy; microstructural design; heat treatment; mechanical properties.

1. Introduction

Nickel-based alloys are widely used in aircraft turbines, jet engines and steam turbine power plants with service temperatures up to ~700 ^{o}C, because of their high temperature corrosion, fatigue and creep resistance [1-3]. Inconel 718 is a Ni-based superalloy strengthened primarily by γ”-Ni_3Nb and γ’-$Ni_3(Al,Ti)$ precipitates and which is generally processed by conventional metallurgical routes such as forging (for disks and shafts) and casting (for turbine frames with larger size and more complex geometries) [4-7]. However, owing to the slow cooling rate during solidification, the cast components have coarse grain size, dendritic segregation and solidification defects, leading to poor mechanical properties. Moreover, in a wrought form it is difficult to control the performance of this material and produce complex geometries [8,9].

Selective laser melting (SLM) is an additive manufacturing (AM) process that offers several advantages compared to conventional technologies, like reduction of production steps, high flexibility, low material consumption and, the most importantly, the possibility to manufacture parts with high geometrical complexity and dimensional accuracy. However, due to the complexity of the non-equilibrium SLM process, such problems as residual stresses, porosity, directional grain growth, microsegregation, creation of non-equilibrium phases, and other process induced defects have to be systematically studied. In order to avoid the occurrence of undesirable microstructural features,