Multi-functional Inconel 718 - Pure Copper parts fabricated by 3D Multi-Material Laser Powder Bed Fusion: a novel technological and designing approach for rocket engine

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Currently, most aerospace components are under extreme operating conditions such as high fluid pressure, mechanical loads, and thermal stresses [1,2]. The structural integrity of the component is assured by the use of high strength and temperature resistant materials as well distinct cooling mechanisms [1,2]. Inconel 718 (Inc718) is usually used in aerospace components (e.g rocket engines) due to their resistance to oxidation (due to the presence of Ni and Cr) and because withstand high mechanical stress at high temperatures. However, one of the main drawbacks of Inconel alloys is their low thermal conductivity (~11 W/m.K) [3] which makes difficult heat extraction of the combustion chamber at high-temperature and pressure conditions as well as reduces its energy efficiency. Moreover, these alloys display low expansion at these temperatures and offer creep resistance [4]. In regeneratively cooled rocket engines, the choice of material, with high thermal conductivity leads to an increase in heat transfer rate and so thermal efficiency [5].

Pure Copper (Pure Cu) is an exceptional thermal conductor (about 397 W/m.K) [6], with resistance oxidization in fuel-rich non-corrosive gas mixtures. However, its reflectivity and thermal conductivity have been an obstacle when processing this powder by laser powder bed fusion [7]. Carlos [7] reported the production of Pure Copper specimens by LPBF with more than 50% porosity, with poor consolidation and low mechanical strength. The joining of different materials such as Inconel 718-16SS, Ti6Al4V-Inconel

718, TiBw/Ti6Al4V composites - Inconel 718 [8] multi-material solutions have been reported in the literature. Residual stresses and defects (such as cracks) on the interface have been the main obstacles when producing multi-material specimens by additive manufacturing processes [9,10].

This technology can be disruptive once by using optimized processing parameters and low solidification times, the diffusion phenomenon can be avoided, and consequently, the formation of fragile and undesirable intermetallic phases [11]. In this regard, this study explored the use of a new Multi-Material Laser Powder Bed Fusion system to combine two completely distinct materials (Inc718 and Pure-Cu) with unique and specific properties (high strength and high thermal conductivity, respectively) in one single multi-functional component for improving heat extraction of a rocket engine. 3D multi-material metal-based parts were produced by using a new home-made 3D Multi-Material-Selective-Laser-Melting (3DMMSLM) equipment developed at CMEMS (Center for Microelectromechanical Systems) at the University of Minho.

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