

3D Multi-Material Laser Powder Bed Fusion: an innovative 420 stainless steel-Cu solution for plastic injection molds

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The plastic injection molding industry is one of the fastest-growing industries in the world since it produces a huge amount of plastic-based components of various types and sizes for the electronics, automotive, pharmaceutical, and aerospace industries [1,2]. However, although it presents numerous advantages (high dimensional and geometric precision, repeatability, and adaptability to a wide range of materials), the costs associated with the mold and machine are high and, therefore, this process is only profitable for mass production. Thus, a fast process is required in order to quickly amortize the initial costs. In this sense, the reduction in the cycle time, more specifically the cooling time (~70 % of the cycle), has been a never-ending challenge, since it has a direct influence on the production costs [3]. Several solutions have been implemented to solve this problem, namely the use of conformal cooling channels and high thermal conductive inserts [4,5]. In particular, Laser Powder Bed Fusion (LPBF) has been used in the fabrication of components with high geometric complexity for cooling systems in industrial heat transfer cases, namely in plastic injection molding industry [5].

Steel alloys are frequently used for the fabrication of plastic injection molds due to the excellent combination of essential characteristics required. 420 stainless steel is one of the steels most used due to its high strength, hardness, and corrosion properties. However, one of the main drawbacks is its low thermal conductivity (25 W/m.K), which makes it difficult to cool the mold after the injection cycle [6]. Therefore, copper and its alloys have been used in mold inserts due to high thermal conductivity (~400 W/m.K).

However, pure copper is a very soft and ductile material, and therefore it is not a good option in the production of the mold's core and cavity [4]. A suitable and high-advanced manufacturing strategy is necessary for combining dissimilar materials in the same part and thus, combine unique properties not possible to obtain using single material's solutions. In recent years, different studies about multi-material solutions produced by additive manufacturing have been reported in literature, 420SS-TiN, 420SS-Inconel 718, 420SS-300 maraging steel, H13 steel-copper, 316L stainless steel-C18400 alloy [7–11]. In this sense, this study is focused on the production of 420 stainless steel-copper solutions produced by 3D multi-material laser powder bed fusion for plastic injection molds. This novel material's design concept allows combining the high mechanical resistance of the steel alloy and high thermal conductivity of the copper. The processing strategies and the transition between dissimilar materials is one of the most challenging and important aspects both from mechanical and metallurgical point of view.

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