3D Multi-Material-Selective-Laser-Melting: technology, fabrication and prototypes

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Abstract

Contrarily to nature, human traditional strategies and inventions both from process and products point of view, use brute force, heavy and inefficient, single and inanimate material (like brick, steel and glass) solutions with unoptimized architectures [1] . To create and developed superior engineering solutions, advanced manufacturing technologies are necessary to evolve from mono-material to multi-material components, from mono-scale to multi-scale added parts, from limited geometries to almost any geometry. Recent man-made use additive technologies and in particular powder-based technologies which possess some principles, similar to nature, where the component is grown, step by step, sequentially. A suitable and high-advanced manufacturing and engineering strategy is necessary for combining dissimilar materials in the same part and thus, combine different and advantageous properties not possible to obtain using single material's solutions. The available approaches on this subject include composites or coating solutions as well as unidirectional functionally graded materials which typically exhibit large diffusion areas with excessive residual stresses in the interface regions and consequent delamination or cracking [2,3]. When regarding, AM, a few studies have shown unidirectional multi-material metal-based parts such as Ti6Al4V-Invar, Ti6Al4V-Steel, Ti6Al4V-Inconel, Ti6Al4V-Al12Si, 316LSS-Cu10Sn, Inconel-Copper, and other examples [4–9]. In this sense, this study is focused on 3D multi-material design and fabrication trough an Additive

Manufacturing (AM) powder-bed-fusion technique. 3D multi-material metal-based parts were fabricated 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. This new home-made manufacturing equipment, allows materials gradations design, in three dimensions thus allowing the creation of mechanical interlocking in the gradation zones, in different directions, therefore reducing eventual detrimental effects of the chemical transition, e.g. intermetallics or other less resistant phases. This novel material's design concept allows, for example, the development of a new acetabular cup capable of combining CoCrMo alloy wear resistance and Ti6Al4V alloy bone-friendly nature, in a single component, fabricated at once. The processing strategies and the functional transition between dissimilar materials with a mechanical interlocking is one of the most challenging and important aspects in this study both from mechanical and metallurgical point of view. The morphological and mechanical results of the fabricated prototypes (Ti6Al4V-CoCrMo, 420SS-Cu, Ti6Al4V-CuNi2SiCr and Inconel 718-Cu) evidence that a solid metallurgical bonding in the interface between the distinct materials is achieved, as evidenced by the low diffusion area with absence of cracks. In fact, a functional transition is also obtained through a design capable to provide a 3D mechanical interlocking thus, assuring simultaneously tensile and compressive strength.

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