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INFLUENCE OF PROCESSING PARAMETERS ON MECHANICAL PROPERTIES OF MULTI-MATERIAL COMPONENTS FROM ALUMINIUM AND COPPER – MANUFACTURED BY LASER-BASED POWDER BED FUSION

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1. Introduction

Nowadays Additive Manufacturing (AM) is gaining ground for producing metallic parts and products. Over the past years, the exploitation of AM processes aims to produce highly complicated mono-material parts in a short time and as a monolithic component. For metallic materials the most common process is powder fusion of metal using a laser beam (PBF-LB/M). Recently, the possibility to manufacture parts with more than one material on the same part using PBF-LB/M has gained increasing attention. The variation of the material's chemical composition throughout a component, also referred to as multi-material components, enables for a more flexible design of the product, e.g. [1, 2]. Examples from the open literature include the combination of mechanical strength as well as temperature resistance or even thermal conductivity properties, e.g. [3-5]. Other examples involve the trade-off between hardness measurements and toughness values [6, 7] or in another cases the sensor integration [8, 9] by AM of dissimilar materials. The multi-materials concept aims to manufacture sustainable-by-design new products with higher performance in e.g. mechanical or thermal properties as well as weight reduction, allowing for the efficient and sustainable use of critical raw materials.

In the present contribution, a multi-material combination of CW106C powder, referred hereafter as CuCr1Zr, and EN AW-4046 powder, referred hereafter as AlSi10Mg, with sharp transition zones, printed in different directions and manufacturing sequences of the two materials, is investigated. For the validation of the approach and the characterization of the transition zones, the manufactured samples were investigated and characterized using optical microscopy, scanning electron microscopy, hardness profile measurements and tensile tests. Furthermore, the density of the transition zones was analysed by image data processing. CALPHAD based computational tools were employed to predict microstructural evolution and solidification behaviour upon AM processing of the sharp transition zone, providing insight and supporting experimental investigations. The feasibility of the presented methods is shown and the production of defect-free transition zones with controlled expansions for multi-material solutions via PBF-LB/M is presented.

2. Materials and methods

The present study simulates the production phase of high performance automotive – power electronics sensing / cooling end-products. In this product, Al and Cu alloys were used, where the Cu alloy could serve as functional material for electricity or heat conduction purposes. CuCr1Zr was selected to serve for heat conduction purposes, while adding Chromium (Cr) and Zirconium (Zr) to the Cu matrix increases material strength as well as heat and wear resistance without significantly affect its heat and electric conductivity capabilities. The Al alloy AlSi10Mg, was selected as the main structural material of the product/component. It is a precipitation-hardenable cast alloy with good electric conductivity and increased chemical stability in corrosive environments.

All samples were manufactured on a customized SLM280HL PBF-LB/M machine (Nikon SLM Solutions Group AG, Germany). The system has a divided recoating system and a suction unit to apply and remove different powder materials and Argon was used as inert gas and a silicone rubber lip as a recoating device. Different process parameters were used to produce the interfaces, namely laser power in [W] and scan speed in [mm/s]. For the validation, various cuboid samples were prepared with the two different build sequences (CuCr1Zr built on AlSi10Mg and vice versa) with transition zones in the z-direction. Additionally, samples with their transition zones in the x–y plane were fabricated using different parameter combinations in the transition zone. These multi-material test specimens were manufactured for quality analysis and evaluation of the components by determining the density and mixing in the joint zone, as well as through mechanical tests such as hardness measurements. Additionally, reference samples were also manufactured for comparison purposes.

3. Results and conclusions

Initially, the manufactured samples were investigated and characterized using optical microscopy to select the process window for achieving the most defect-free interfaces possible between the two metallic materials. For the intended defect-free interfaces of the produced materials, the geometrical dimensions of the interfaces as well as hardness profile measurements were performed. Furthermore, the density of the transition zones was analysed by image data processing. Finally, calculation results indicate the formation of brittle phases in the transition zone, which may limit processability. The feasibility of the presented method is shown and to produce defect-free transition zones with controlled expansions for multi-materials via PBF-LB/M is pursued.

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