Induction assisted laser-based directed energy deposition of NiAl-Cr alloys by in-situ powder mixing: microstructure and defect formation

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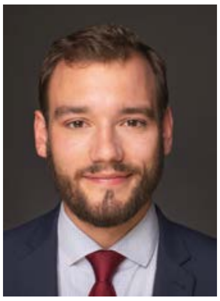

Abstract

Introduction: NiAl-based alloys are promising candidates for high temperature applications. However, their limited ductility and fracture toughness at room temperature have prevented the transfer to industrial applications so far [1]. Especially the eutectic alloy NiAlCr34, forming an in-situ composite consisting of B2-NiAl and α-Cr, has attracted much attention as this alloy design can yield a tremendous increase in fracture toughness compared to other NiAl-based alloys [2]. In addition, Förner et al. [3,4] showed how high cooling rates that are present in additive manufacturing can improve the mechanical properties in comparison to cast material. Within this study, the processing of NiAlCr34 by laser-based directed energy deposition with blown powder using in-situ mixing of pre-alloyed Ni50Al50 and elemental Cr is investigated. Additionally, induction heating as a possibility to overcome the challenge of crack formation due to high thermally induced stresses is analyzed.

Results: Energy dispersive X-ray spectroscopy (EDS) showed that by in-situ mixing of the two powders the targeted alloy composition could be obtained. Powder flow measurement during the deposition showed stable powder feeding behavior despite the simultaneous feeding of two powders. Combined X-ray diffraction and EDS confirmed the presence of the two phases B2 NiAl and α-Cr. Scanning electron microscopy showed that the microstructure exhibits a lamella spacing below 200 nm. In hardness measurements values as high as 650 HV0.1 were obtained. Induction heating with temperatures up to 900 °C was used to reduce cracking in fabricated samples. However, especially in multi-layer bulk material samples computed tomography showed the formation of severe cracking. An adaption of the sample geometry yields an improvement of the cracking susceptibility but cannot completely prevent the cracking.

Summary and conclusion: The investigations showed that powder mixing can be successfully applied to achieve in-situ alloying. Hence, especially for alloy development this technique has high potential to speed up the screening of a broad spectrum of alloy compositions. The microstructural properties and the hardness are promising but much lower than the values obtained by electron beam powder bed fusion in [3]. Moreover, the formation of cracking in multi-layer build-ups that could not be prevented despite high temperature preheating is a major challenge that needs to be overcome. However, since small structures, such as single tracks, could be manufactured without cracking, induction assisted DED of NiAlCr34 can be considered as a promising technique for maintenance and repair applications for components made of NiAlCr34 or similar alloys.

Literature

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