Title

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**Abstract**

This review paper investigates the state of technology for multi-material (MM) manufacturing of metals utilizing additive manufacturing, in particular powder bed fusion processes. The study consists of three parts, covering the material combinations, the MM deposition devices, and the implications in the process chain. The material analysis is clustered into 2D and 3D MM approaches. Based in the reviewed literature, the most utilized material combination is steel-copper, followed by fusing dissimilar steels. Secondly, the MM deposition devices are categorized into holohedral, nozzle-based as well as masked deposition concepts and compared in terms of powder deposition rate, resolution and manufacturing readiness level (MRL). As a third aspect, the implications in the process chain are investigated. Therefore, the design of MM parts and the data preparation for the production process are analyzed. Moreover, aspects for the reuse of powder and finalization of MM parts are discussed. It is found, that there are theoretical design approaches, but no specific parameter studies or use cases are presented. Principles for powder separation are identified for exemplary material combinations, but results for further finalization steps of MM parts could not be found. In conclusion, 3D MM manufacturing has a MRL of 4 – 5, which indicates that the technology can be produced in a laboratory environment. According to this maturity, several aspects for serial MM parts need to be developed, but the potential of the technology has been demonstrated. Thus the next important step is to identify lead applications to foster the further technology development.

**Keywords** Keyword 1 · Keyword 2

1. Introduction and motivation

Functionally Graded Materials (FGM) are characterized by a variation …Klicken oder tippen Sie hier, um Text einzugeben..

1. Definitions

Several AM processes allow the manufacturing of material combinations and FGM. The investigation of this paper is focused to metal-based PBF processes, which is set into the context of the seven functional AM principles in Figure 1.



Figure 1: Focus of the review in the context of AM principles

A holistic definition of multi-material in the context of ….

1. Main Chapter(s)

The literature review presented in this paper is based on two leading statements, which are derived from the research objective. The first leading question clarifies, if a literature source describes a multi-material approach under the scope of this ….

parallel to the powder coating direction [25] combined with a hybrid manufacturing approach (see: section 4.1). Anstaett and Anstaett et al. presented a solution with separation of the powder chambers perpendicular to the coating direction [13, 22, 30–32]. 3D-MM capability is achieved by a suction unit, which removes unsolidified powder material after exposure of the respective layer with the laser. Without lowering the build plate the second powder material can be applied to the same layer. After solidifying the second material the build plate is lowered and the process is repeated.

* 1. Sub-chapters
1. Conclusion and outlook

The vision for multi-material (MM) manufacturing through AM is to produce parts that utilize different materials specified by local requirements. Thus it is a functionally graded material (FGM) with a discrete or graded material transition. In this review, the focus is set on metal MM manufacturing by powder bed fusion (PBF) processes. The current state of research is summarized in Figure 5, following the process steps of the generalized AM process chain.

1. Acknowledgement

The authors express their sincere thanks to …

1. Contributions
2. Appendix

References



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