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# Manufacturing of carbide tools by Selective Laser Melting

Eckart Uhlmann[a, b], André Bergmann[a*], Robert Bolz[b]

[a]*Fraunhofer Institute for Production Systems and Design Technology (IPK), Pascalstraße 8-9, Berlin 10587, Germany*
[b]*Technische Universität Berlin – Institute for Machine Tools and Factory Management (IWF), Pascalstraße 8-9, Berlin 10587, Germany*

**Abstract**

Application fields of electrical discharge machining (EDM) are limited due to given process conditions. When producing structures of high aspect ratios or using multi-axis machining, removed particles assemble at the machining zone, leading to process instabilities and increasing tool wear. A promising approach to improve EDM process conditions is the utilization of flushing channels in the tool electrode. However, with increasing complexity of the electrode geometry and the local integration of the mentioned flushing channels, conventional electrode manufacturing reaches its limitations. By applying Selective Laser Melting (SLM), these limitations are eliminated. An additional benefit is the efficient use of material during SLM, where nearly no waste is produced, because remaining powder can be used for the next SLM-process. The appropriate integration of flushing channels, even for complicated electrode geometries, improves process conditions during EDM in a variety of applications, leading to a higher material removal rate $V_W$ and reduced tool wear $\vartheta$ compared to machining without flushing. Additionally, the number of required tool electrodes can be reduced, as SLM enables an efficient integration and miniaturization of all features in a single electrode, what results in a far more sustainable process chain. Of particular interest in the field of EDM is carbide. Because of its wear resistance and stability, it is an ideal electrode material, which is commonly applied in µEDM. Tungsten carbide-cobalt is representative for this group of materials, which is already used in tool manufacturing. Several tests show a general suitability of carbide tool electrodes made by SLM for EDM-processing. However, the SLM process parameters and the composition of the carbide-cobalt show significant impact to the EDM results. A lower proportion of cobalt leads to reduced material removal rates, whereas the level of tool wear remains at a similar level. In order to benefit from the advantages of additive manufactured carbide tool electrodes, this investigation aims at decreasing waste of material and the number of required tool electrodes.


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*Keywords:* additive manufacturing, selective laser melting, electrical discharge machining, tungsten carbide

*Corresponding author. Tel.: +49 (0)30-390-06-107; fax: +49(0)30-391-10-37.
E-mail address: andre.bergmann@ipk.fraunhofer.de

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## 1. Introduction

Increasingly complex market requirements demand high product variation of manufacturing industries. This results in flexible manufacturing systems (FMS) where alongside product variation a shorter lifespan of the manufactured goods can be observed. This long-term trend has led to a reduction of production batch sizes. Therefore, industries need manufacturing technologies which are able to combine productivity and flexibility in order to equip for competition in those markets.

Within the presented context, special and unique tools play a major role. These tools must be designed and manufactured for small and medium enterprises, also fitting for machines and process parameters commonly employed by them. These new design and manufacturing systems can also mean a higher usage of such unique tools than of typical ones. However, developing such special tools has a very high initial cost. Consequently, despite their improved performance, special tools are hardly employed in a large-scale production. To target this market, innovative FMS processes manufacturing special tools are required.

Recent developments of additive manufacturing processes (AM) have proved an excellent opportunity to match all requirements for this market [1, 2]. Especially selective laser melting (SLM) enables manufacturing of near-net-shape complex parts, scanning and melting metal powder layer by layer. This substitutes multistage shaping processes (pressing, milling and drilling) in toolmaking, resulting in significant reduction of the process chain, which can lead to the reduction of time and costs [3, 4].

The following work aims at presenting an approach on how to manufacture carbide tool electrodes for electrical discharge machining (EDM) in a shortened FMS by SLM processing. In contrast to conventional manufacturing processes of EDM tool electrodes, the SLM process eliminates steps of complex cutting operations to achieve free form geometry and provides advanced design possibilities. Especially the use of carbide is advantageous for EDM applications, as the wear resistance and stability of carbides are ideal for tool electrode material, resulting in a smaller number of required tool electrodes. The process of SLM provides an economic and sustainable machining of carbide tool electrodes. Among carbides, tungsten carbide cobalt is most commonly employed in the tool manufacturing industry and provides sufficient electrical conductivity $\kappa$ for EDM processing.

## 2. Conventional and additive manufacturing process chain for tool making

Production of special interior contoured tools, such as milling tools or EDM electrodes, made of carbide undergoes a time- and cost-intensive multistage sintering process. After the powder has been directly pressed into a green body, a complex multistage shaping process is applied in order to achieve the required geometric complexity. The integration of flushing channels in tool form electrodes leads to great difficulties, whereby the resulting positional and dimensional accuracy are only achievable to a limited extent.

An alternative for cost-effective flexible and automated production is offered by SLM. In a shortened process chain customized tools can be manufactured energy- and resource-efficiently and in small batch sizes. Conventional preparatory work as well as production stages are significantly reduced (see figure 1) and take place digitally in the framework of computer aided manufacturing (CAM) data processing.