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Die-sinking EDM of a SiC-boride-composite

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Abstract
Silicon carbide-based composites are highly demanded for industrial applications, like heat exchangers in corrosive environments. In consequence of the mechanical properties like high hardness H and brittleness, cutting processes are still challenging. An opportunity for processing difficult-to-cut materials with sufficient electrical conductivity σ is electrical discharge machining (EDM). In order to develop suitable machining technologies, known parameters for common material combinations can serve as a starting point. Hence, standard technologies from the database of a commercial die-sinking EDM machine tool were applied for machining a silicon carbide-boride-composite. The material removal rate Q_W and the arithmetical mean deviation Ra for finishing and roughing operations are observed. The formation of cracks and the extend of the typical deposition layer formed at the surface of the workpiece is analysed through scanning electron microscopy. While the material removal rate Q_W is increasing with higher discharge energies W in this investigation, the arithmetical mean deviation Ra is not dependent on this property. Furthermore, spalling is identified as main material removal mechanism occurring in this process. Overall, the machinability of silicon carbide-boride composites with EDM, applying commercial available parameter technologies, is successfully demonstrated.

Keywords: silicon carbide composite, die-sinking EDM, parameter technologies

1. Introduction

There is an increasing demand for silicon carbide based composites for applications in the aerospace, automotive and energy sector. The reason for that are the high resistance of this material in high temperature and high corrosion environments [1]. Because of high hardness H and brittleness, processing these materials with conventional manufacturing methods is time consuming and therefore expensive [2, 3]. In order to overcome these limitations, die-sinking electrical discharge machining (S-EDM) can be applied to those ceramic composites with sufficient electrical conductivity σ, because no mechanical forces F occur and the fabrication of complex shapes is possible [2, 3, 4]. Challenges of processing ceramics with EDM arise from typical material removal mechanisms like spalling, which can lead to a poor surface quality [5]. Furthermore, high temperatures T at the surface of the workpiece can lead to the formation of a deposition layer and micro-cracks, which compromises the mechanical and thermal stability [6]. To optimise machining efficiency and to avoid those effects, machining technologies need to be developed for ceramic composites. Finding parameter combinations can be time consuming due to the high complexity of the process and the lack of starting parameters. However, since EDM is a well-established machining process, technologies for common material combinations and machining regimes have been generated in the past. One approach to solve the aforementioned problems is to adopt those settings for processing silicon-carbide composites and serve as starting point for experimental strategies for parameter optimizations. Thus, this study aims to investigate the machinability of a silicon carbide-composite with S-EDM in hydrocarbon oil, when industrial available parameter technologies, designed for different material combinations, are applied.

2. Experimental setup

The experiments for this study were conducted on the commercial die-sinking EDM machine tool Genius 1000, Zimmer & Kreim GmbH & Co. KG, Brensbach, Germany, using the oil-based dielectric fluid Ionoplus IME-MH distributed by oelheld GmbH, Stuttgart, Germany. All workpieces were made out of a silicon carbide-boride-composite (SiC/B) developed by FCT Ingenieurkeramik GmbH, Frankenblick, Germany. Cavities with a depth t = 0.5 mm were produced in triplicate during all experiments. Electrolyte copper rods served as tool electrodes for this experiments. Machining technologies, designed for machining steel with copper electrodes and stored at the internal database of the EDM machine tool, were studied. This included parameter for finishing (F), semi-roughing (SR) and roughing operations (R). The ignition voltage U, discharged current I, pulse duration t_{on} and pulse-off time t_{off} of these technologies are displayed at table 1. Moving from technology F to R corresponds to an increase in the discharge energy W.

Table 1. Applied machining technologies

technology	U [V]	I [A]	t_{on} [µs]	t_{off} [µs]
F	270	1.5	5	10
SR	270	6.7	40	24
R	270	9.5	50	30

In order to evaluate the feasibility of these commercial available parameters for machining the SiC/B, the material removal rate Q_W and the arithmetical mean deviation Ra of the cavities were evaluated. Additionally, thermal induced cracks and the deposition layer at the workpiece surface were observed with scanning electron microscopy (SEM).

3. Results of the experiments

The results for material removal rate Q_W and arithmetical mean deviation Ra of the experiments are depicted in figure 1. The material removal rate Q_W varies between the values $0.01\ mm^3/min \leq Q_W \leq 0.07\ mm^3/min$, as is shown in figure 1 a. Hence, the material removal rate Q_W is increasing when higher discharge energies W are applied. In contrast, the arithmetical mean deviation Ra is nearly the same for finishing and roughing operations, shown in figure 1 b. This property is only varying between $1.50\ \mu m \leq Ra \leq 1.68\ \mu m$. This can be explained, if spalling is considered as the main material removal mechanism and the size of the removed particles is related to the grain size d_G of the material used in this experiment. Figure 2 shows a SEM-image of a cross-sectioned cavity machined with the parameters belonging to the roughing technology with a magnification factor of 100. Although the highest degree of heat inflicted surface damage can be expected in case of this technology, no cracks due to thermal shock appear in the bulk material. Moreover, no deposition layer can be observed on the surface of the workpiece. In addition, fragmentary particles, broken from the surface, can be seen in figure 2. These particles can be interpreted as debris from the EDM-process, which were not removed by the flushing. This would be an indication for the suspected material removal mechanism of spalling.

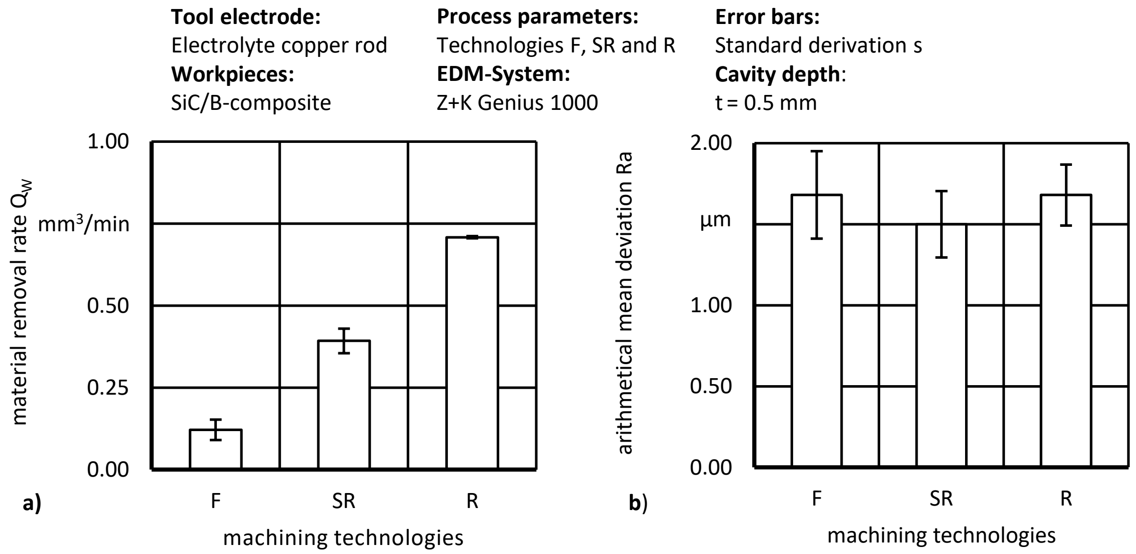

Figure 1. Comparison of a) material removal rate Q_W and
b) arithmetical mean deviation Ra for cavities with depth t = 0.5 mm on SiC/B for machining technologies F, SR and R

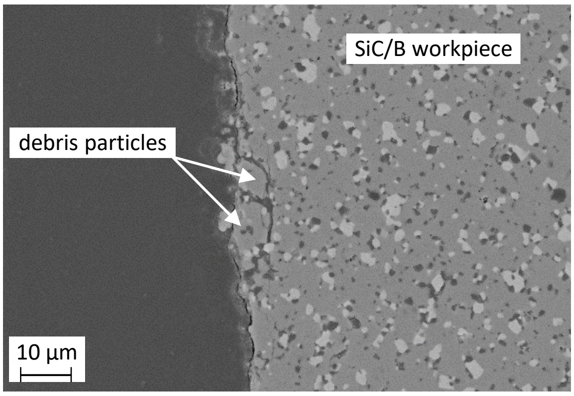

Figure 2. Surface integrity of cross-sectioned cavity produced by applying roughing technology

4. Summary

The findings of this investigation show that commercially available machining technologies can be applied for the manufacturing of silicon carbide-boride-composites. No surface damage due to high temperatures T could be found and the arithmetical mean deviation Ra is not dependent of the machining regime. The second finding can be related to the specific material removal mechanism of spalling. Higher material removal rates Q_W were achieved through increasing the discharge energy W. Further research is needed to confirm these observations and enhance machining efficiency.

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References

[1] Tkachenko, Y. G.; Britun, V. F.; Prilutskii, E. V.; Yurchenko, D. Z.; Bovkun, G. A. : Structure and Properties of B_4C-SiC Composites. Powder Metallurgy and Metal Ceramics, 2005, p. 196 – 201.

[2] Singh, B.; Kumar, J.; Kumar, S.: Influences of Process Parameters on MRR Improvement in Simple and Powder Mixed EDM of AA6061/10%SiC Composite. Ceramics International, 2016, p. 1,597 – 1,610.

[3] Saxena, K. K.; Srivastava, A. S.; Agarwal, S.: Experimental investigation into the micro-EDM characteristics of conductive SiC. Materials and Manufacturing Processes, 2015, p. 303 – 312.

[4] Liw, P. J.; Nurlishafiqa, Z.; Ahsan, Q.; Zhou, T.; Yan, J.: Experimental investigation of RB-SiC using Cu–CNF composite electrodes in electrical discharge machining. The International Journal of Advanced Manufacturing Technology, 2018, p. 3,019 – 3,028.

[5] Ji, R.; Liu, Y.; Zhang, Y.; Wang, F.: Machining performance of silicon carbide ceramic in end electric discharge milling. Int. Journal of Refractory Metals and Hard Materials, 2011, p. 117 – 122.

[6] Kunieda, M.; Lauwers, B.; Rajurkar, K. P.; Schumacher, B. M.: Advancing EDM through Fundamental Insight into the Process. CIRP Annals, 2005, p. 64 – 87.