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Effect of Process Parameter on Material Rate Removal in Die-Sinking Electrical Discharge Machining using Uncoated and Coated Electrode

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ABSTRACT

Electrical Discharge Machining is used to machine complex shapes with a high accuracy and materials such as carbides, heat resistant and super alloys which are difficult to machine. Dies are tools used to cut or shape materials into a solid product. EDM method is used to create these dies, despite the size or commonness of the shape needed. In this study, influence of electrodes and technological parameters including (curent (I), pluse on time (Ton) and pulse off time (Toff)) on machining productivity in EDM with coated and uncoated electrodes is investigated. SKD61 material is used to studied, electrode Cu, TiN and TiAlN-coated electrodes are also investigated. Taguchi method is used to design the experiment. The experimental results showed influence degree of technological parameters on MRR.

Keywords: EDM, MRR, SKD61, Coated electrode

1. INTRODUCTION

Ti-6Al-4V is one of the most widely used alloys due to its ability to retain exceptional physical properties even at high temperatures [1]. The various proper-ties of these alloys embody the light weight associated with high strength, excel- lent resistance to fatigue and creep, good protection in corrosive environments, and biocompatibility. Ti-6Al-4V is used in various fields such as automotive industry, biomedical industry, aerospace industry, marine industry and chemical process industry. Non- conventional machining methods such as laser processing and electrochemical methods, electro discharge machining process are recommended for machining of Ti-6Al-4V [2]. and Electro discharge machining process is the best process to machine such materials [3].

The effect of vibrations on the electrical discharges in the micro-EDM process was investigated in many researhs [4]. The experiments were performed on steel strip of 1 mm thickness and tungsten carbide rod served as electrode rod. The effect of tool rotation, pulse on time and workpiece vibration has been investigated on MRR and SR [5]. It was evident that by application of vibration onto the micro-EDM process, the machining time can be reduced significantly. The reduction or elimination of the start-up process delivers a significant part of the machining time savings. Process time decreases with increased vibration frequency and constant amplitude. Causes for the start-up process are arc discharges and the resulting retracting movements of the tool electrode, which leads to an open circuit state. The total duration of the arcing events is reduced by the application of vibration and decreases with increasing frequency. Surface defects such as inhomogeneity, cracks, arc spots and black spots have been analyzed and reduced, while improving material removal rate with lower tool wear [6]. Superfinished surfaces thus generated have uniform white layer (re-solidified layer) with an average thickness below 1µm. Copper was used as the tool electrode and hot-work steel was used as the workpiece [7]. Super-finished surfaces having Ra <0.06µm have been generated using die sinking EDM in meso-micro scale using a novel stochastic orbiting strategy and a low stray capacitance power circuit. The stochastic orbiting strategy reduces the pre-polishing requirement of the tool electrode. Ra values as low as 0.05µm and evenly distributed white layer (re-solidified layer) with thickness of less than 1µm can be achieved with milled, turned or wire-eroded copper electrodes having Ra ≤ 0.2 µm [8]. Optimization of micro-EDM drilling of inconel 718 super alloy studied [9]. Inconel 718 nickel-based super alloy flat plates in 4.76 mm thickness were used as the target material while copper as tool electrode. The process parameters were current and pulse on time to investigate tool wear rate and Surface roughness. They conclude that the pulse current has greater effect on multiperformance characteristics than pulse duration parameter. Electrode wear were increased with the increase in both discharge current and pulse duration almost linearly due to the higher energy density [10]. The crack and damage characteristics of machined surfaces were reduced by decreasing the discharge current and shortening the pulse duration.

2. EXPERIMENTAL SETUP

SKD61 steel is a commonly used material for manufacturing hot stamping die, mould and injection mould with small and medium sizes. EDM is still a commonly used solution for shaping surfaces of moulds. Therefore, improving processing efficiency in this field is necessary and has high practical significance. The dimension of SKD61 steel worrkpiece is 10x10x5 mm. Copper electrode had taken as the base electrode for experimentation and it coated with various materials comparative study of coated and non coated tool electrodes. The electrode has a diameter of 6mm, and its length is 25mm. The choice of dielectric fluid depends on the specific application and the actual production cost. The dielectric fluid selected for this experiment is D323 oil. This is the most commonly used oil in pulse machining fields. The experimental investigations were conducted on a CHEMER EDM machine type (CM 323C, Taiwan). Among the available methods, Taguchi design is one of the sophisticated DoE methods for analyzing of experiments. It was widely recognized in many fields particularly in development of new products and processes in quality control. The Taguchi experimental design reduces cost, improves quality, and provides robust design solutions. The advantages of Taguchi method over the other methods are that numerous factors can be simultaneously optimized and more quantitative information can be extracted from fewer experimental trials. Orthogonal array for final experiments with three levels of eletrode, pulse on time (Ton) and pulse off time (Toff) are shown in Table 1. Experimental readings were recorded for L9 orthogonal array (three input parameters and three levels) to study MRR. Experimental results are mentioned in Table 1.

Table 1. Experimental L9 orthogonal array for final experiments

Exp.	Electrode	T_{on}(µs)	T_{off}(µs)	I(A)	MRR (mg/min)
1	Cu	12	5.5	3	0.0117
2	Cu	25	12	6	0.0386
3	Cu	50	25	8	0.0729
4	TiN	12	12	8	0.0383
5	TiN	25	25	3	0.0134
6	TiN	50	5.5	6	0.0192
7	TiAlN	12	25	6	0.0222
8	TiAlN	25	5.5	8	0.0266
9	TiAlN	50	12	3	0.015

3. RESULT AND DISCUSSION

3.1 Influence of coated and uncoated electrodes on MRR

Electrode material not only affects on wear durability of electrodes, but also affects directly on formation process of sparks based on physico-mechanical properties, electrical conductivity, thermal conductivity and structural structure of the material. In this study, the used electrode affects significantly on MRR, and influence degree is the second, as shown in Figure 1. Figure 2 shows that coating layer affects significantly on machining productivity. MRR of the electrode Cu is highest and MRR of the TiAlN-coated electrode is smallest. This problem may be that the conductive, thermal conductivity and physicochemical characteristics of Cu materials are the most suitable for the formation and discharge of sparks. Compared with electrode Cu, the MRR of the TiN-coated electrode is reduced by 42.43% and the MRR of the TiAlN-coated electrode is reduced by 48.20%.

Response Table for Means

Level	Electrode	Ton	Tof	I
1	0,04105	0,02407	0,01915	0,01336
2	0,02126	0,02617	0,03064	0,02666
3	0,02363	0,03571	0,03616	0,04592
Delta	0,01979	0,01164	0,01701	0,03256
Rank	2	4	3	1

Fig. 1. Levels of influence of technological parameters on MRR

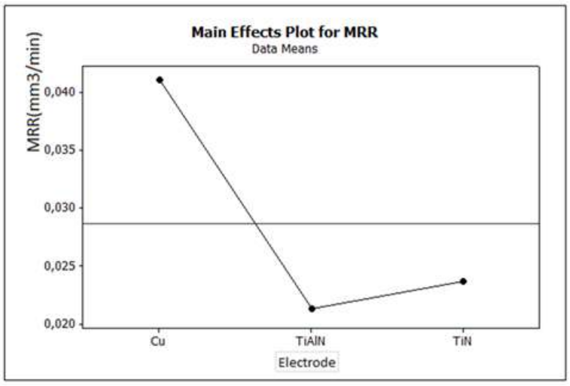

Fig. 2. Influence of coated and uncoated electrodes

3.2 Influence of curent (I)

In EDM, curent (I) is the most importance parameter, it affects directly on energy of spark formed. Increase of curent (I) will be proportional to the increase in the energy of the sparks. Curent (I) affects significantly on MRR, as shown in Figure 1. MRR increases when curent (I) increases, as shown in Figure 3. This problem is that the pulsed energy for the spark formation process when curent (I) increases, therefore, the spark energy also increases, and the amount of workpiece material which are melted and evaporated increases. Compared with curent (I = 3 A), MRR of current (I = 6 A) increased by 99.55% and MRR of current (I = 8 A) increased by 243.71%.

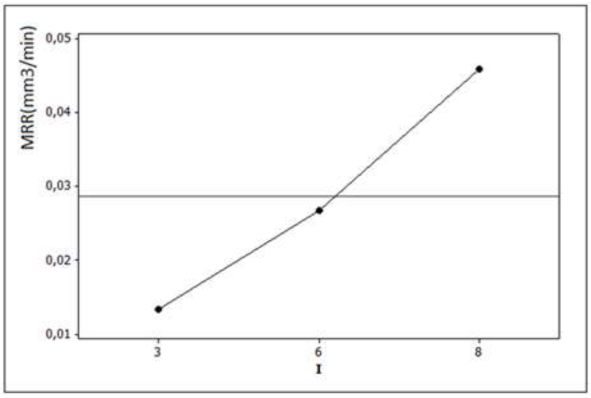

Fig. 3. Influence of curent (I) on machining productivity

3.3 Influence of pusle on time (T_{on})

Influence of pulse on time (T_{on}) on machining process in EDM is the same influece of curent (I). MRR increases when pulse on time (T_{on}) increases, howerver, influence degree of pulse on time (Ton) on MRR is smaller than current (I). Compared with 4 investigated parameters, influence of Ton is smallest, as shown in Figure 1. Figure 4 shows that MRR increases significantly when Ton increases from 12 to 50 µs. Compared with Ton = 12 µs, MRR increased by 8.72% and 43.31% when T_{on} = 25 µs and T_{on} = 50 µs, corresponding. This problem is that spark discharge energy and time increase when Ton increases. Howerver, T_{on} will affect directly on chip removal process and refresh of dielectric solution if T_{on} is too high. This will affect on the stability of the machining process and the machining productivity may be reduced when the T_{on} is too large.

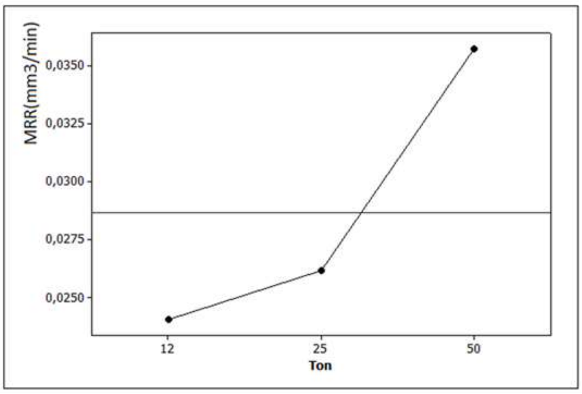

Fig. 4. Influence of T_{on} on MRR

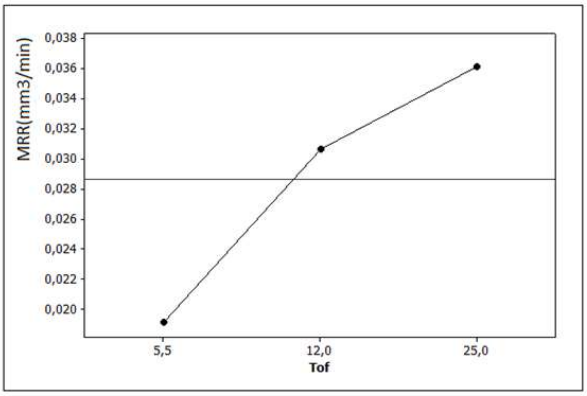

Fig. 5. Influence of T_{off} on MRR

3.4 Influence of pusle off time (T_{off})

Pusle off time (T_{off}) will affect directly on real machining time in EDM. Normally, spark discharge time decreases when T_{off} increases, therefore, productivity decreases.

However, if machining time is too short, chip removal time from the discharge gap is reduced and dielectric solution is not enough time to refresh completely. This will decrease the stability of the machining process, short-circuit phenomena will occur with a higher frequency and machining productivity and machined surface quality are also reduced. Machining productivity increases when Toff is from 5.5 to 25 µs, as shown in Figure 5. This problem may be that stability of machining process increases when T_{off} increases during investigated time of T_{off} of experiment process. Compared with T_{on} = 5.5 µs, MRR increased by 60% and 88.82% when T_{on} = 12 µs and T_{on} = 25 µs, corresponding.

4. CONCLUSION

This research evaluated influence of electrodes and some technological parameters on machining productivity in EDM with coated and uncoated electrodes. Some conclusions are as follows:

- The curent (I) is the technological parameter that has the strongest influence on the MRR, followed by the electrode material and the smallest influence one is T_{on}.

- Coated layer on electrode surface affected on MRR. Compared with uncoated electrode, MRR of TiN-coated electrode reduced by 42.43% and MRR of TiAlN-coated electrode reduced by 48.20%.

- MRR increases significantly when curent (I) increases. Compared with I = 3 A, MRR of curent (I = 6 A) increases approximately 99.55% and MRR of curent (I = 8 A) increases 243.71%. MRR is improved significantly when pusle on time (T_{on}) increases. Compared with T_{on} = 12 µs, MRR of pusle on time (T_{on} = 25 µs) increases approximately 8.72% and MRR of pusle on time (T_{on} = 50 µs) increases 43.31%.

- MRR increases significantly when pusle off time Toff increases. Compared with Toff = 5.5 µs, MRR of pusle off time (T_{off} = 12 µs) increases approximately 60% and MRR of pusle off time (T_{off} = 25 µs) increases 88.82%.

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