Clarification and Solution of Depth-dependent Tool Wear and Removal Rate in Micro Electrical Discharge Drilling

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Abstract

In this study, the characteristics of tool electrode wear and removal rate with the processing depth in micro electrical discharge drilling were investigated, in order to realize a lower tool wear and higher removal rate. Experiments were carried out by using deionized water and oil dielectric as the machining fluid. It was found that using deionized water greatly reduces the tool electrode wear, and increases the machining rate. Also, the machining depth has a significant impact on the machining rate and the tool electrode wear. In order to solve the problem that hole drilling stops at a certain depth in the case of deionized water, the tool electrode shape was modified and the effectiveness was verified experimentally.

1 Introduction

In micro electrical discharge drilling (MEDD), due to small discharge energy and difficult debris removal, the machining rate decreases and the tool wear increases significantly with the processing depth. Therefore, to increase the removal rate and reduce the tool electrode wear are two key issues in MEDD. Although a lot of researches of micro-EDM using oil dielectric and deionized water have been reported [1][2], the investigation on the change of the machining rate and tool wear with the processing depth is not enough. In this study, the machining characteristics with the drilling depth for different machining fluid were investigated, in order to realize a higher machining rate and lower tool wear in MEDD.

2 Experimental setup

In this study, a tungsten tool electrode, fabricated with the wire electrical discharge grinding

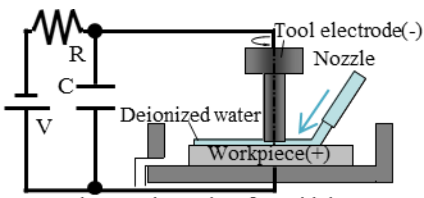


Fig. 1 Schematic of machining

(WEDG) [3], was used to drill holes on a stainless plate with a micro-EDM machine (MG-ED71, Panasonic). Figure 1 shows the schematic view of experimental setup. In order to prevent electrolytic action, fresh deionized water was supplied consistently to the workpiece surface from the ultra-pure water equipment (Puric-Z2, Organo Corp.), when deionized water was used. Meanwhile, the workpiece was immersed in the dielectric in the case of using oil dielectric. During drilling, the tool electrode was fed at the setup speed, and the electrode was pulled back when short-circuits occurred. The tool electrode was fed again after short-circuits disappeared.

3 Depth-dependent characteristics for different machining fluid

Experiments were carried out under machining conditions shown in Table 1, when setting a tool feed length of 900 μm to drill a blind hole.

3.1 Machining rate

Table 1 Machining condition

Capacitance	100 pF
Open voltage	80 V
Feed rate	3 μm/s
Tool electrode	Tungsten,Φ60 μm
Workpiece	SUS304
Oil dielectric	CASTY-LUBE EDS
Deionized water	18 MΩ・cm

By obtaining the hole machining depth from the tool position, tool wear and an assumed gap-width, the time variation of machining depth was derived. Then, the relationship between the machining rate and the depth was obtained by dividing the machining depth change with the corresponding time at different depth. The result is shown in Fig.2. From the figure, it is found that the machining rate for deionized water is about 10 times higher than that for oil dielectric, up to the depth of 300 μm. However, the machining stops after the machining depth reaches 300μm in the case of deionized water. The reason is considered that frequent short-circuit occurs because the debris removal from the machining area becomes difficult at that machining depth.

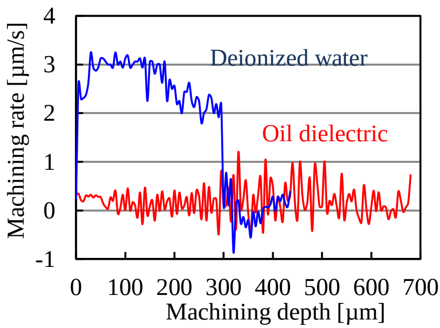


Fig.2 Machining rate vs machining depth

3.2 Wear ratio

The tool wear was observed when blind hole drilling was performed by varying the tool feed amount from 100 to 900 µm by an interval of 100 µm. The degree of tool wear was evaluated by the volumetric wear ratio, defined as the ratio between the tool wear volume and the workpiece removal volume. The wear amount corresponding to a certain machining depth was obtained from the change in the tool electrode shape before and after machining, which was measured with an optical microscope (VH-Z50L, made by Keyence). On the other hand, the removal amount was obtained from the change in the tool position, and an assumed gap-width by taking the tool wear into consideration. Meanwhile, the tool wear ratio obtained from experiments is an average up to each machining depth. The tool wear ratio at each machining depth was then calculated with the method proposed by the authors [2], and shown with the average one in Fig.3. The result shows that the wear ratio in the case of oil dielectric increases greatly with the machining depth and much larger than that in the case of deionized water.

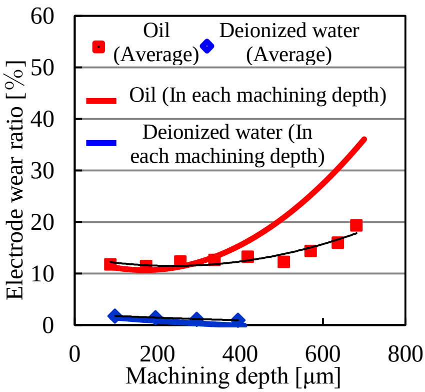
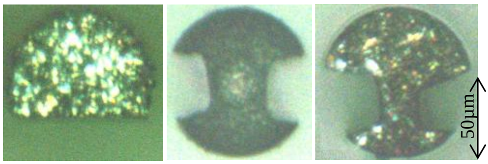


Fig.3 Wear ratio vs machining depth

4 Measures to drill deeper hole by using deionized water

The experimental results in the above section show that the machining rate is much faster and the wear ratio is much smaller in MEDD using the deionized water than that using the oil dielectric. However, the most obvious defect for the deionized water is that there exists a limitation in machining depth. In order to remove debris from the machining area, decreases the short-circuit occurrence, and finally deepen the machining depth, four types of tool with different shape were tried; a) the tool with a straight cut on one side (D-cut), b) the tool with two straight grooves on both sides, c) the tool with two oblique grooves of 5 degree on both side, and d) the conventional cylindrical electrode. Three of them except the cylindrical one are shown in Fig.4 and 5. The aim of the D-cut and straight groove electrode is to broaden the space for the debris removal, while the additional aim for the oblique groove electrode is to use the force caused by the rotation and the slope of groove to enhance the effect of debris removal. To see the effect obviously, an open voltage of 60 V, lower than that in the former experiments, was used. The machining depth limitation for each electrode is shown in Fig.6. It is found that by using three proposed tools, the depth limitation is increased about 2.8 times comparing to the cylindrical electrode. This is considered because electrode with D-cut or grooves helps circulate machining fluid and promote the debris removal from machining area. However, the expected difference between the tools with oblique and straight grooves has not been confirmed. The degree of oblique grooves may be too small to obtain enough force to remove debris.

Fig.4 View of oblique tool



(a) D-cut (b) 0° groove (c) 5° groove

Fig.8 Section of electrode

Fig.5 Section of tool electrode

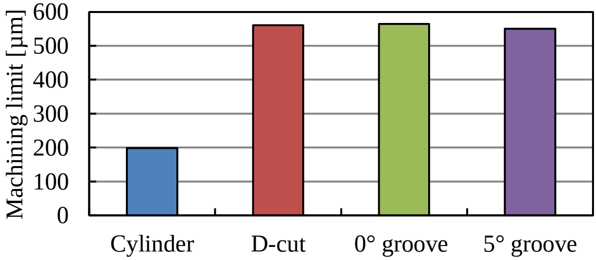


Fig.6 Maximum machining depth

5 Conclusions

Experiments of MEDD were carried out by using deionized water and oil dielectric, and the measures to drill deeper holes with tool electrodes with different shape were proposed. It was found that the deionized water is good at machining speed and tool wear. Also, the effectiveness of D-cut and groove tool electrodes for deeper hole drilling was verified experimentally.

References:

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