Improvement of Micro-EDM Characteristics by Applying Ultrasonic Vibration to Machining Fluid

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Abstract

The existence of debris in the inter-electrode area in micro-EDM interrupts the machining process. Applying ultrasonic vibration to the machining fluid helps circulate the machining fluid and remove the debris from the gap area, and thus reduce short-circuits and abnormal discharges. In this study, the effect of applying ultrasonic vibration to machining fluid in micro-EDM was experimentally investigated. It is found that a significant increase in the machining speed is realized by applying ultrasonic vibration. Also, with the vibration of the machining fluid, micro-hole drilling with ultra-small discharge energy becomes possible.

1 Introduction

Although micro-EDM has its potential in micro part manufacturing [1], the machining speed is quite low due to short-circuits and abnormal discharges, because of the difficult debris removal from the narrow gap-width. Up to now, several methods were proposed in order to deal with the debris in the gap area in the EDM process. For example, the application of ultrasonic vibration to the tool electrode [2] and machining fluid [3] helps circulate the machining fluid and remove the debris from the gap area, and thus reduce short circuits and abnormal discharges.

In this study, the effect of applying ultrasonic vibration to the machining fluid in micro-EDM was experimentally investigated, in order to realize higher machining speed and deep-hole drilling.

2 Experimental setup

In this study, micro-hole drilling was carried out with a micro-EDM machine (MG-ED82W, Panasonic) to investigate the machining characteristics of ultrasonic vibration assisted micro-EDM. A tungsten electrode with a diameter of 40 μm, fabricated with the wire electrical discharge grinding (WEDG) method [4], was used in this experiment. The power supply was an RC discharge circuit. The tool electrode was mounted on the rotation spindle whose position was controlled in the Z-direction, while the workpiece was mounted on the NC XY stage. The schematic layout of the ultrasonic vibration device (SC-450SP, Taga Electric Co.), the tool electrode, and the workpeice is shown in Fig.1. The ultrasonic vibration was applied to the machining fluid through the horn.

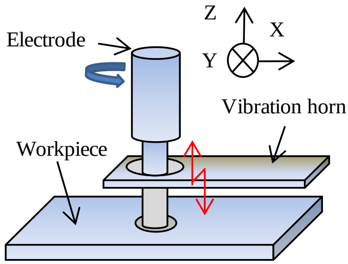


Fig.1 Layout schematic of machining device

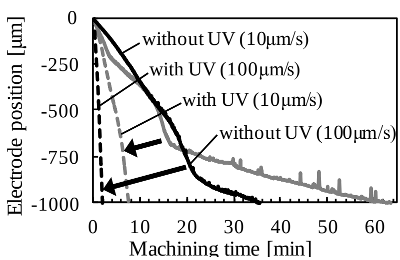
3 Characteristics of ultrasonic vibration assisted micro-EDM

It was predicted that if ultrasonic vibration was applied to the machining fluid, it would help circulate the machining fluid and remove the debris from the gap area, and thus improve the machining speed. In order to investigate the effect, experiments under the following two situations were carried out: using rotation only, and using both rotation and ultrasonic vibration under different preset tool speeds.

Table 1 Machining conditions

Tool electrode	Tungsten φ 40 μm
Workpiece	SUS304,t 800 μm
Frequency	43±1.5 kHz
Flexural amplitude	4μm (p-p)
Machining oil	CASTY-LUBE EDS

The micro-holes were machined with an open voltage of 110 V and a capacitance of 3300 pF. The other machining conditions are shown in Table 1.



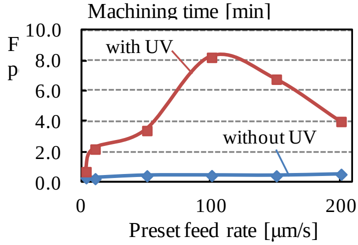


Fig.3 Relationship between average feed rate and preset feed rate

Figure 2 shows the change of the electrode position with the machining time under a preset tool speed of 10 μm/s and 100 μm/s. It is found that the machining time is shortened by 93% by applying ultrasonic vibration to the machining fluid. Figure 3 shows the relationship between the average tool feed rate and the preset feed rate. Here, the average tool feed rate is defined as the ratio of the electrode feed distance and the machining time. It was found that in the absence of ultrasonic vibration, the average tool feed rate is quite low and changes slightly. However, the average tool feed rate increases with an increase in the preset feed rate up to 100 μm/s, and then decreases with ultrasonic vibration. The reason is attributed to the faster feed of the tool electrode because of the effective removal of debris and less short circuits, due to the ultrasonic vibration of the machining fluid. Meanwhile, when the preset tool feed rate becomes larger than 100 μm/s, short circuits occur frequently because of the faster tool feed rate, thus leading to a decrease in the average tool feed rate.

4 Effect of ultrasonic vibration under ultra-small energy conditions

Accurate micro-holes can be machined with ultra-small discharge energy, for example, a low open voltage and the stray capacitor in the RC discharge circuit. However, machining with ultra-small discharge energy is difficult as the removal of debris from the gap area becomes difficult because of the small energy and the narrow gap-width. The effect of applying ultrasonic vibration is thought to become obvious under ultra-small energy conditions. Experiments under the following four situations were carried out: (a) without rotation and ultrasonic vibration, (b) with only rotation, (c) with only ultrasonic vibration, and (d) with both rotation and ultrasonic vibration. The hole drilling was finished when the tool electrode was fed at 100 μm, or the machining time reached 30 min, under the same machining conditions as shown in Table 1.

Figure 4 shows the relationship between the electrode position and machining time under an open voltage of 40 V. It was found that the hole drilling was finished after only 1 minute with rotation and ultrasonic vibration; quite faster than other situations. The reason is considered to be that the rotation and ultrasonic vibration helps circulate the machining fluid and therefore efficiently remove the debris from

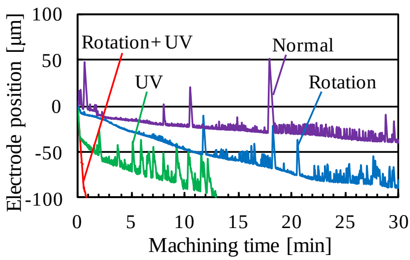


Fig.4 Relationship between electrode position and machining time (40V)

the gap area. In addition, the electrode feed in the case of both rotation and ultrasonic vibration coincide well with that of only rotation until the electrode is fed at about 35 µm. Subsequently, only the machining with rotation and ultrasonic vibration could maintain a constant feed rate. The combination effect appears after the micro-hole is drilled to a certain depth.

Figure 5 shows the relationship between the electrode position and the machining time under an open voltage of 16 V, which is the lowest voltage that can be set in the machine. It was found that hole drilling is impossible without the assistance of ultrasonic vibration under this smallest discharge energy condition. The smoother feed in Figure 5 also shows that the combination of ultrasonic vibration and rotation helps to reduce short circuits.

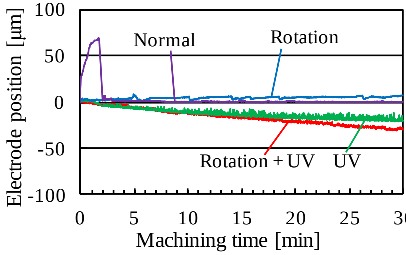


Fig.5 Relationship between electrode position and machining time (16V)

5 Conclusions

In this study, to improve the machining speed, micro-hole drilling was carried out by applying ultrasonic vibration to machining fluid.. The effects of ultrasonic vibration on hole drilling were investigated. It was found that the machining time is greatly shortened by applying ultrasonic vibration. Also, machining under ultra-small discharge energy is realized when ultrasonic vibration is applied.

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