Effect of Thin Electrode with Grooves for High Machining Speed in Small Deep Hole EDM

Hiroki TOYODA[1, a], Hideki TAKEZAWA[2,b*], and Kenta YUASA[3,c]

[1] Kogakuin University, 2665-1, Nakanomachi, Hachioji, Tokyo, Japan
[2] Kogakuin University, 2665-1, Nakanomachi, Hachioji, Tokyo, Japan
[3] Kogakuin University, 2665-1, Nakanomachi, Hachioji, Tokyo, Japan

[a]am17049@ns.kogakuin.ac.jp, [b]htake@cc.kogakuin.ac.jp, [c]am17072@ns.kogakuin.ac.jp

Keywords: EDM, Small Hole Machining, Deep Hole Machining, Machining Speed, Discharge state

Abstract. Small-hole EDM uses brass pipe electrode 0.1 mm to 3 mm in diameter for machining. However, it has been known empirically that the machining speed is declined because of deteriorating discharge state due to insufficient removal of machining debris in high aspect ratio machining. Therefore, in this study, the Straight groove electrode was used for improving removal of debris in order to reduce deteriorating discharge state during deep hole machining. Grooves were machining to normal pipe electrode, and the effect of grooves on small-hole machining was confirmed. In the machining to stainless steel, the machining speed decline in Normal pipe electrode machining. But the reduction of the machining speed could be suppressed in the Straight groove electrode machining. Furthermore, the effect on removing debris of Straight groove electrode was confirmed by investigating discharge waveforms. In the result, the number of times of Normal discharge decreased in the region where the machining speed was reduced in Normal electrode. On the other hand, it was found that when Straight groove electrode was used, the number of times of Normal discharge did not decrease so that no reduction in machining speed occurred. As a result, the effect of the Straight groove electrode to Small-hole EDM was confirmed.

Introduction

Small-hole EDM injects machining fluid by using brass pipe electrode to remove debris during machining. However, it is known empirically in the deep and small hole machining, the machining speed is declined and the deteriorating discharge state due to insufficient removal of debris is related machining speed. In the Micro-hole EDM, which uses electrodes with diameter of 0.1 mm or less, some experiments have shown that the machining speed improved by adding grooves to electrode in the forming process [1,2] . Furthermore, giving ultrasonic vibration into deep hole machining by EDM can improve the machining efficiency [3]. Therefore, in this study, the Straight groove electrode that made by machining to Normal pipe electrode was applied Small-hole EDM. That was used for improving removal of debris and the effect on machining speed was verified. The Small-hole EDM experiments were conducted by using Normal electrode and Straight groove electrode and confirmed that effect on machining speed. Moreover, the effect on removing debris of Straight groove electrode was evaluated by analyzing discharge states during machining.

Discharge Condition

Small-hole EDM machine (ASTEC Co.,Ltd. A22M) was used to machining experiments. The 3 mm brass pipe electrodes were used to machining experiments. Straight groove electrodes were made by additional machining to Normal pipe electrode which explained previously. The electrode was rotating during machining. The Small-hole EDM machine does not have an isopulse generator so it allows control only the pulse duration. Discharge duration become short when an ignition delay time was occurred.

Production of the Straight groove electrodes

3 mm diameter Normal pipe electrodes were used for machining experiment. Straight groove electrode was made additional machining by cutting to same electrode. A simple metal die for groove cutting in Fig.1 was cut out by wire EDM. Its diameter is 20 mm and it has been die shape at the center of die. The metal die thickness is 10 mm, but in order to prevent deformation of the electrode, only the die portion was machined to 3 mm. The cutting method is shown in Fig. 2. The metal die was fixed to a Normal purpose lathe, pipe electrode was fixed to the bite holder and it was pulled out and cut the groove. Three straight grooves were cut over a length of 300 mm by this method. The brass pipe electrodes with a diameter of 3 mm, a length of 400 mm and a wall thickness of 0.5 mm were used. The groove depth was produced to target 0.25 mm. Fig.3 shows cross section of Normal and Straight groove electrode. When the groove depth of electrode after cutting was measured, it was around 0.22 mm on average so it was formed slightly shallow.

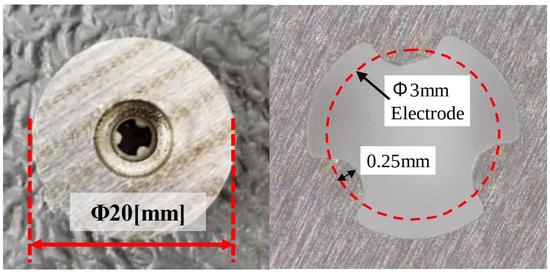

Fig. 1 Die for groove cutting

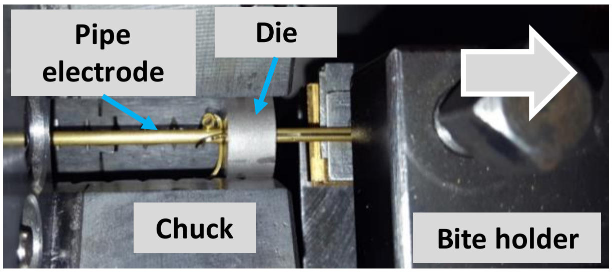

Fig. 2 Method of cutting method using the die

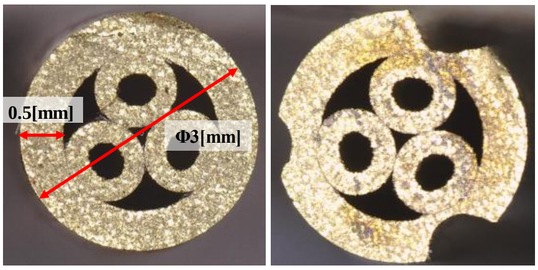

Fig. 3 Cross section photographs of electrodes

Small-hole EDM Experiments (Steel)

Small-hole EDM machining experiments were conducted by using a total of two kinds of electrodes, Normal and Straight groove. Work-piece was steel (AISI 1045). Discharge condition were shown in Table.1. The transition of the descent amount of the main axis with respect to the machining time is shown in Fig.4. The main axis feed is a value obtained by adding machining depth and electrode wear length together. Straight groove electrode did not improve the machining speed compared with the Normal electrode. In Normal pipe electrodes machining, the reduction of the machining speed did not appear even in the region where machining depth was deep. So we considered that the difference due to the presence or absence of the groove was not clarified.

Table.1 Discharge conditions

Pulse duration	Duty factor	Discharge Current	Machining fluid injection pump pressure
150 μs	94%	9.6 A	1 MPa

Small-hole EDM Experiments (Stainless Steel)

Small-hole EDM machining experiments was conducted using a Normal and Straight groove electrode. Work-piece was stainless steel (AISI 304) and that height was 125mm. The transition of the descent amount of the main axis with respect to the machining time is shown in Fig.5. In Normal pipe electrode machining, it was confirmed that the machining speed declines in the region where the main axis feed becomes large. This is a well-known phenomenon in the machining of small-hole EDM, it is believed that the declining of removal efficiency of debris influences discharge state. A similar tendency has been confirmed experimentally in the study on the Micro-hole EDM[1]. On the other hand, in the machining of Straight groove electrode, work-piece were pierced through without declining the machining speed even if the main axis feed exceeded 100 mm. Further, in the region where the depth of the main axis feed was 80 mm or less, the machining speed was the same regardless of the shape of the electrode. From these results, it was found that reduction of the machining speed can be suppressed for the Straight groove electrodes in the region where the machining speed declined in the machining of Normal electrodes.

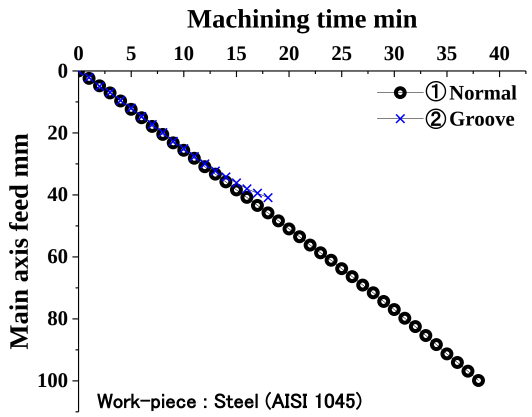

Fig. 4 Transition of the main axis with respect to the machining time (Steel)

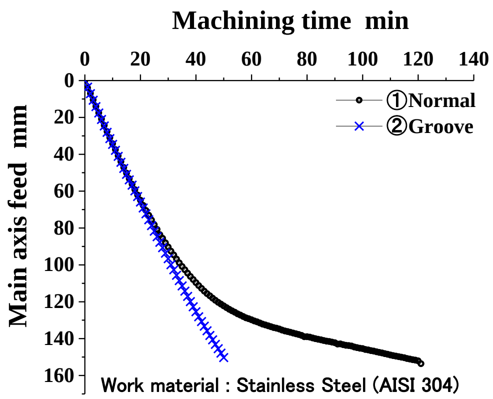

Fig. 5 Transition of the main axis with respect to the machining time (Stainless Steel)

Analysis of the Discharge Waveform (Stainless steel)

As described above, in Normal electrodes machining, the machining speed declined when main axis feed reached to a certain depth during machining in Stainless steel machining. Although it is considered discharge state was stable for a while after the start of machining. However, it is believed that the discharge state becomes unstable due to the influence of debris in deep machining region. On the other hand, in the Straight groove electrode in which the machining speed did not decline, it can be inferred that a stable discharge state was maintained even if the machining depth becomes large. Therefore, discharge waveforms during Stainless steel machining at each electrode were observed and classified. Using the oscilloscope (Teledyne LeCroy), both discharge voltage and current waveforms were recorded for 5 ms at an interval of once every three seconds at the same time. Waveforms were classified into five minutes after the main axis reached 70 mm where the machining speed did not decline and about five minutes were classified after reaching 120 mm where the machining speed decreased with Normal pipe electrodes. The total number of observed discharge waveforms were 2850 waveforms. The waveforms were classified into the following five. Fig.6 shows pattern diagrams of waveform about five kinds of discharge waveform. The first one is Normal discharge. Its discharge duration is 150 μs and it is a preferable discharge. The second is ignition delayed. Its discharge duration is shorter than Normal discharge because of ignition delay time. Open has no discharge occurring. Short indicates that a short circuit is occurring between the electrode and the workpiece. Other was regarded as both short circuit and discharge occurred.

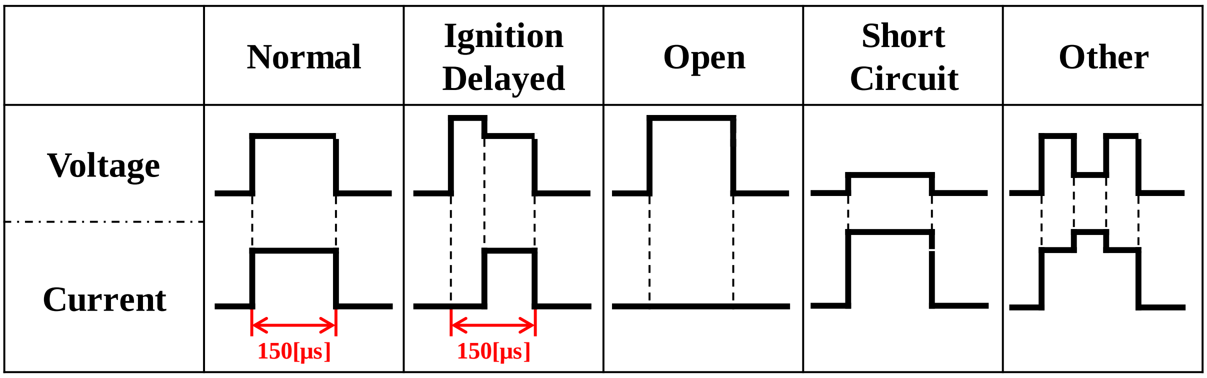

Fig. 6 Classification of discharge waveforms

Fig.7 and Fig. 8 show the results of classification of discharge waveforms. Fig.7 is the results of data for five minutes after the main axis reached 70 mm and Fig.8 shows the results of data for five minutes after the main axis reached 120 mm. In Fig.7, there are no significant differences in the number of Normal discharges between Normal and Groove electrodes. On the other hand, in the region where the main axis feed was large, the Normal discharge frequency decreased and Open state frequency increased when the Normal electrode was used as shown in Fig.8. However, the number of the Normal discharges has not decreased on Straight groove electrode data as compared with Fig.7. From this result, it was found that when the machining depth becomes deeper, the machining speed decreases in the Normal electrode machining because the number of Normal discharges was reduced. When the movement of the main axis during machining was visually observed, pulling up of the main axis repeatedly occurred in a region where the machining speed was declined. This phenomenon appears when the discharge state becomes unstable and it is cause of Open waveform frequent. In other words, it can be inferred that the discharge becomes unstable due to removal of debris was stagnant. And the pulling up action of the main axis occurs during machining as conventionally shown. On the other hand, in the case of Straight groove electrode, the discharge state was stable when the machining depth becomes deep. This result shows removing debris was favorable, so the discharge state does not become unstable during machining include deep region.

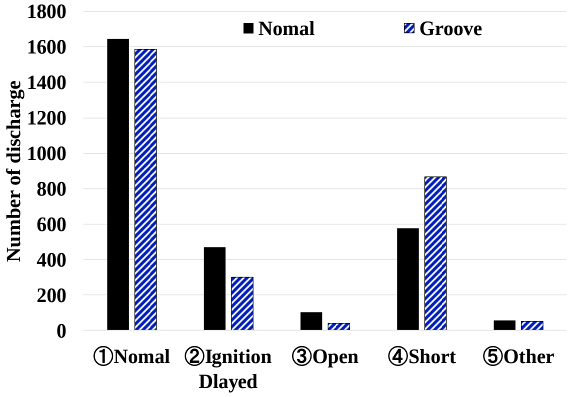

Fig. 7 Classification of discharge state at 70 mm machining depth

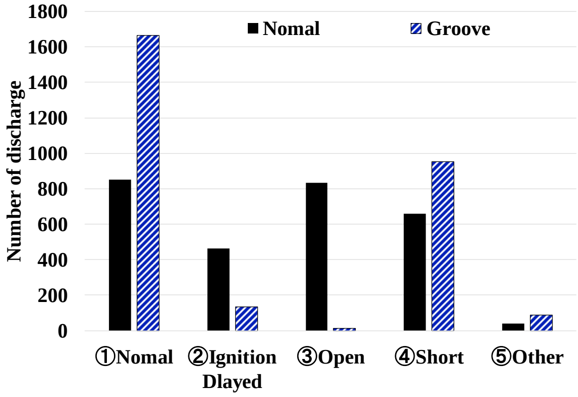

Fig. 8 Classification of discharge state at 120 mm machining depth

Summary

In Small-hole EDM, the effect of Straight groove electrode on improving machining speed and stabilizing discharge state were confirmed, and the following was clarified.

[1] In the machining into steel, no significant difference in the machining speed occurred between Normal and Straight groove electrode.
[2] On stainless steel workpiece machining, there was a region where the machining speed declined when the Normal electrode used. However, the reduction of the machining speed could be suppressed in the Straight groove electrode machining.
[3] As the result of discharge waveform analysis, Straight groove electrode had a larger number of Normal discharges compare with Normal electrode in the region where the machining depth was deep. It is considered that a stable discharge was occurred as a result of promoting removal of machining debris when Groove electrode was used.

Acknowledgements

This study is financially supported by the MAZAK Foundation.

References

[1] Takumu MIYAMOTO, Tomohiko ICHIKAWA and Wataru NATSU, Influence oftool electrode shape on depth machining limit in micro EDM, Society for PrecisionEngineering Spring Conference Academic Conference Proceedings, (2013), pp.519-520.

[2] Masashi MACHIDA, Wataru NATSU, Flow analysis of working fluid in micro electrical discharge drilling process, Proceedings of the 14th euspen International Conference, 2014, pp.107-111

[3] Zhao Wansheng, Wang Zhenlong, Di Shichun, Chi Guanxin and Wei Hongyu, Ultrasonic and Electric Discharge Machining to Deep and Small Hole on Titanium Alloy, Journal of Materials Processing Technology, 120, 1-3 (2002) 101-106.