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Optimization of dielectric oil resistivity for high-performance wire EDM

*Shixian Liu[1], Akira Okada[2], Tomohiko Kitamura[3]

[1]Graduate School of Natural Science and Technology, Okayama University
[2]Faculty of Natural Science and Technology, Okayama University
[3]Idemitsu Kosan Co., Ltd.

liushixian_ntmlab@s.okayama-u.ac.jp

Abstract

Deionized water has been conventionally used as dielectric fluid in wire EDM, while oil in die-sinking EDM. The gap distance using dielectric oil is smaller than that using deionized water, since the electric resistivity of dielectric oil is higher. In addition, EDM in oil can prevent oxidization and anodization of machined surface. For these reasons, dielectric oil has been recently used also in wire EDM for achieving high-precision machining. However, the influence of dielectric oil properties on wire EDM characteristics has not been clarified sufficiently. This study fundamentally investigated the influence of dielectric oil resistivity on wire EDM characteristics. Two types of dielectric oil differing only in resistivity were examined.

Linear cutting experiments were carried out using these oils at first. The experiment results showed that the removal rate becomes higher and machined surface roughness becomes smaller with the decrease of dielectric oil resistivity. Furthermore, the machined kerf width increases with the decrease of dielectric oil resistivity.

Next, the influence of resistivity on dielectric breakdown distance was investigated to discuss the cause of the change in machined kerf width, and it was found that dielectric breakdown distance increases with the decrease of dielectric oil resistivity. In addition, discharge location distribution during machining using each dielectric oil were evaluated, and it was found that the discharge distribution becomes uniform due to wide kerf in the case of lower resistivity oil.

From these results, it can be considered that the debris exclusion improves with wide kerf due to the large dielectric breakdown distance. Therefore, the removal rate and machined surface roughness are improved with the decrease of dielectric oil resistivity.

Keywords：Wire EDM, Dielectric oil, Resistivity, Removal rate, Surface roughness

1. Introduction

Deionized water has been conventionally used as dielectric fluid in wire EDM, while oil in die-sinking EDM. The gap distance using dielectric oil is smaller than that using deionized water, since the electric resistivity of dielectric oil is higher [1]. In addition, wire EDM in oil produces lower tensile residual stress on the machined surface than that in deionized water [2]. EDM in oil can also prevent oxidization and anodization of machined surface of metal mold steels and cemented carbides. For these reasons, dielectric oil has been recently used also in wire EDM for achieving high-precision machining [3]. Despite the wide use of dielectric oil in wire EDM, the influence of dielectric oil properties on wire EDM characteristics, such as material removal rate, surface roughness, and form accuracy, has not been clarified sufficiently. This study fundamentally investigated the influence of dielectric oil resistivity on wire EDM characteristics. The wire EDM characteristics in linear cutting machining using oils with different resistivity were compared. Then, to clarify the cause of the difference in machining characteristics, the dielectric breakdown distance was measured and compared using oils with different resistivity.

2. Influence of Resistivity on Machining Characteristic

Two types of prototype dielectric oil differing mainly in resistivity, Oil-18-Low and Oil-18, were prepared for this study. The resistivities are 0.0048 and 2.8 TΩ•m, respectively. Table 1 shows the physical and thermal properties of these oils. Since the viscosity and cooling ability, which are considered to have a significant influence on wire EDM performance, have hardly changed, the influence of resistivity only can be investigated with using these two types of oil.

In order to investigate the difference in wire EDM characteristics with dielectric oil resistivity, linear rough cutting experiments were carried out using these oils at first. An alloy tool steel SKD11 (JIS specifications) with a thickness of 1.0mm was used as a workpiece, and a hard brass wire with a diameter of 200µm was used as a wire electrode. The experiments were carried out using a fine wire EDM machine (MAKINO UPV-3).

Fig. 1 shows the comparison of machining characteristics using each type of dielectric oil. The experiment results showed that the removal rate(c) becomes higher and machined surface roughness(a) becomes smaller with the decrease of dielectric oil resistivity. Furthermore, the machined kerf width(b) increases

Table 1 Physical properties of dielectric oil

	Oil-18-Low	Oil-18
Resistivity ρ [at 80℃] TΩ・m	0.0048	2.8
Viscosity μ [at 40℃] mm²/s	1.860	1.849
Density [at 15℃] g/cm³	0.7730	0.7730
Acid value mgKOH/g	0.09	0.01
Specific heat capacity [at 20℃] J/g・K	2.2	2.2

with the decrease of dielectric oil resistivity. In die-sinking EDM, it has been reported that the dielectric breakdown distance increases in lower resistivity oil [4]. This is considered to be the reason of the increase in machined kerf width with Oil-18-Low. Furthermore, the debris exclusion from the gap would be improved with wide kerf. In wire EDM, accumulation of debris in machined kerf usually leads to discharge concentration, which causes deterioration in wire EDM characteristics. Consequently, the discharge concentration might be reduced due to wide kerf in the case of lower resistivity oil, and therefore the wire EDM characteristics are improved.

3. Influence of Resistivity on Dielectric Breakdown Distance

Next, the influence of resistivity on dielectric breakdown distance was investigated. In the measurement experiment of the dielectric breakdown distance, the wire was approached slowly to the workpiece surface polished to mirror surface, and a high-speed camera (KEYENCE VW-9000) was used to observe the distance between workpiece and wire. Fig. 2 (a) shows the schematic diagram of the experiment. A light was applied to observe the edges of the workpiece and the wire, so the discharge light was no longer visible. Therefore, an oscilloscope was connected to the camera, and the timing of discharge occurrence was detected by the signal from the oscilloscope. Fig. 2 (b) shows an example of the observation image when discharge occures. The minimum distance between the wire and the workpiece when the first discharge occurs is defined as the dielectric breakdown distance. The result is shown in Fig. 3. It was found that dielectric breakdown distance increases with the decrease of dielectric oil resistivity, which enlarges machined kerf width as shown in Fig. 1(c).

The high-speed camera was also used to observe the discharge locations during machining in the entire machined kerf, with using each dielectric oil. It was found that discharge concentration occurs less in the case of lower resistivity oil.

4. Conclusion

In this study, the influence of dielectric oil resistivity on wire EDM characteristics was investigated. It was found that EDM characteristics are improved, and machined kerf width increases with the decrease of dielectric oil resistivity. Furthermore, dielectric breakdown distance increases with the decrease of resistivity, which correnspondss with the result of machined kerf width. It can be considered that the debris exclusion from the gap improves with wide kerf due to the large dielectric breakdown distance, which brings a positive effect on machined surface roughness and removal rate. However, the range of resistivity investigated in this study is narrow, and the influence of resistivity on single discharge process should also be investigated to discuss the cause of the difference in machining characteristics. In the furture studies, oils with lower resistivity would be prepared and used. Furthermore, the difference in discharge plasma would be investigated to clarify the influence of resistivity on single discharge process.

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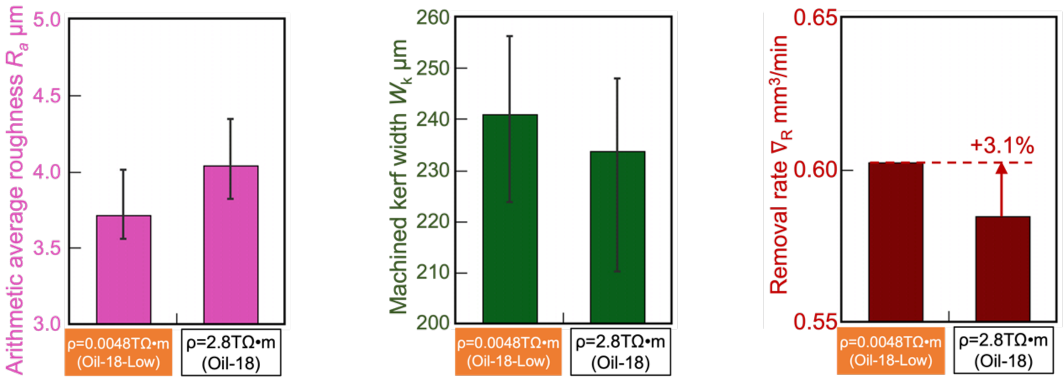
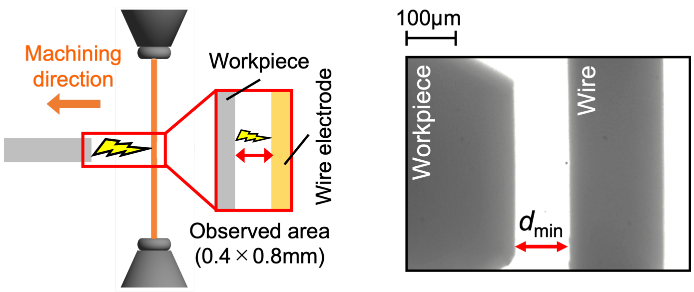


(a) Arithmetic average roughness R_a **(b)** Machined kerf width W_k **(c)** Removal rate V_R

Figure 1. Difference in wire EDM characteristics with resistivity



(a) Observation range (b) Observed image

Figure 2. High-speed observation of dielectric breakdown distance

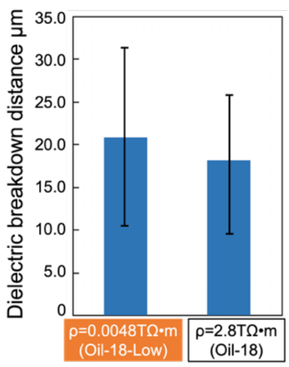


Figure 3. Difference in dielectric breakdown distance with resistivity