Measurement of Machining Force in Lathe Type Electro-chemical Discharge Machine

K. Furutani, K. Arai
Toyota Technological Institute, Japan

furutani@toyota-ti.ac.jp

Abstract

Precision machining methods for insulated materials are demanded in various fields. The authors have proposed a lathe-type machine for electro-chemical discharge machining (ECDM) to machine axisymmetric parts. In this paper, removal mechanism is experimentally investigated by the measurement of machining force with a two-axis force sensor during ECDM. The tangential force at an applied voltage of 40 V was larger than that at 0 V. Soluble and viscous sodium silicate was generated by chemical reaction of silica glass with sodium ion. Removal mainly caused dissolution of the sodium silicate into electrolyte.

1 Introduction

In recent years, high-performance devices are demanded in electronics, optical and medical apparatus in which glass and fine ceramics are often used. Electro-chemical discharge machining (ECDM) has been studied for machining such insulating materials. The authors have proposed a lathe-type ECDM machine [1]. In this paper, machining force during turning by ECDM with a lathe type machine is measured to analyze the removal process experimentally.

2 Principle of electro-chemical discharge machining

In the conventional ECDM, an insulating workpiece is dipped in electrolyte as working fluid, and a tool electrode is pressed against a surface at a small load. With an increase of the applied voltage to the tool electrode, the electrode is covered with generated bubbles then discharge occurs. Because the discharge heat accelerates the chemical reaction between Si and Na components, a rigid bond Si-O-Si is replaced with a softer bond Si-O-Na. In addition, bits of the workpiece surface are sublimed by the discharge heat. Consequently, the workpiece surface is removed [2]. This chemical reaction is denoted as

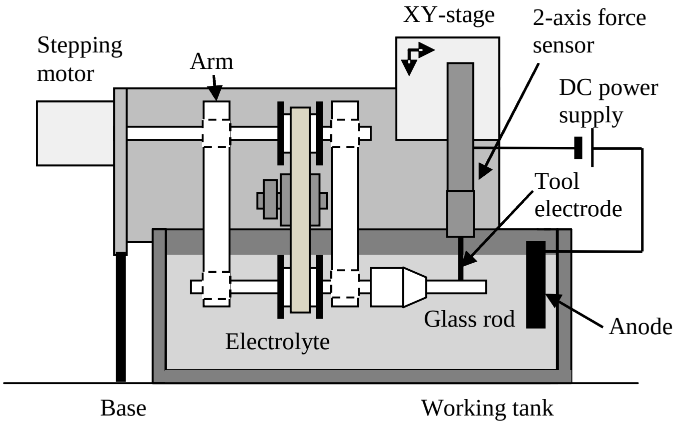


Figure 1: Lathe-type electro-chemical discharge machine

$$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O. \quad (1)$$

Because sodium silicate is a viscous and soluble material, possible removal processes in the lathe type were dissolving into water or scraping off with a tool electrode. A major factor in the removal process was deternined by the following experiments.

3 Lathe-type electro-chemical discharge machine

Fig. 1 shows a structure of the lathe-type ECDM machine. A workpiece was rotated with a stepping motor by means of a toothed belt. The runout of the spindle shaft was 0.06 mm. The normal force was controlled from 0.06 to 0.08 N by detecting with a two-axis force sensor shown in Fig. 2. A set of the strain gauges (1)-(4) was used for the measurement of the normal force, and another set of the strain gauges (5)-(8) was used for the tangential force. The resonance frequencies were 35 Hz for the tangential direction and 62 Hz for the normal one, respectively. A tungsten electrode was thrust into the sensor frame.

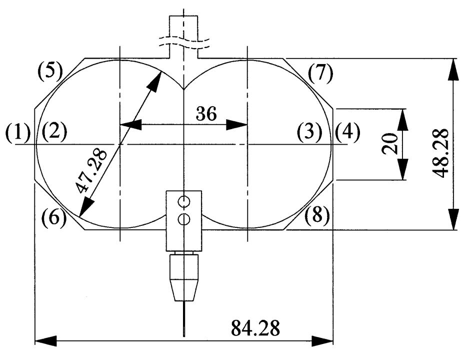


Figure 2: Two-axis force sensor (unit: mm)

4 Experiments

Table 1 shows the machining conditions. The electrolyte was aqueous solution of NaCl. A graphite rod was used for anode to avoid electrolysis. The applied voltage was increased up to 43 V. Fig. 3 shows the relationship between peaks of tangential force for 30 s and the applied voltage. Over an applied voltage of 38 V, discharge occurred and the tangential force was steeply increased with variations.

Fig. 4 shows fluctuation of the tangential force during turning three times. The cycle time of the tangential force at 40 V at the second turn was much longer than that at 0 V at the first and third turns. If the tangential force were disturbed by rough surface at the second turn, the peak tangential force would be kept high after the applied voltage had been decreased to 0 V at the third turn. However, when the applied voltage was decreased from 40 to 0 V at the third turn, the tangential force was decreased. Therefore, the generation of sodium silicate caused the increase of the tangential force at the second turn.

Table 1: Machining conditions

Tool electrode	Tungsten,0.3 mm in diameter
Anode	Graphite
Dipped depth of electrode	2 mm
Workpiece	Silica glass, 5 mm in diameter
Electrolyte	20 wt% NaCl
Machining time	30 min
Rotational speed	1.0 min^{-1}
Applied voltage	0, 10, 20, 30-43 V

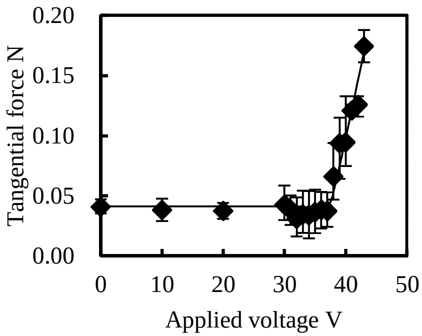


Figure 3: Relationship between tangential force and applied voltage

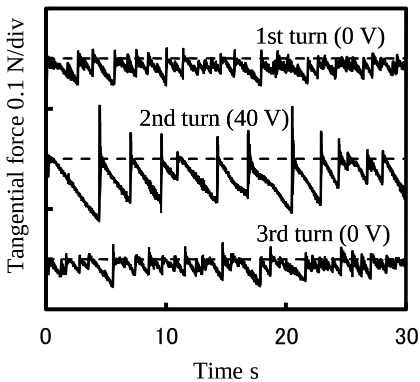
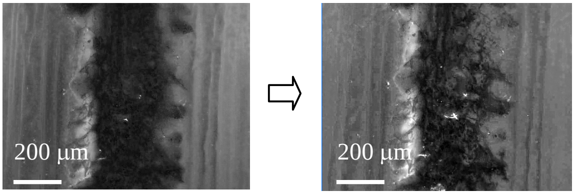
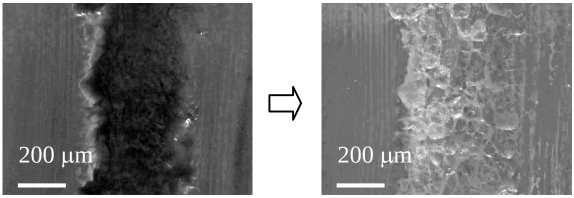


Figure 4: Fluctuation of tangential force



(a) Removal with tool electrode



(b) Exposed in electrolyte for 60 s

Figure 5: Removal of sodium silicate from glass surface

Then 60 wt% sodium silicate solution was spread on a glass rod. The sodium silicate as alkali was stained purple with phenolphthalein. Fig. 5 shows photographs of the rod in which only the red component is extracted from color pictures by image processing and shown as black. When the glass rod surface was scraped with the tool electrode in air, the sodium silicate solution still remained as shown in Fig. 5 (a). However, it disappeared after the rod was dipped into water for 60 s as shown in Fig. 5 (b). Therefore, dissolution of the sodium silicate into the electrolyte was the major removal mechanism of silicate glass in the lathe-type ECDM.

5 Conclusions

The conclusions can be drawn as follows.

(1) The tangential force was increased during ECDM by generated sodium silicate.

(2) The generated sodium silicate was removed by dissolving into water rather than scraping with the tool electrode.

The authors wish to thank Prof. M. Ohno of Toyota Technological Institute for his valuable advice. A part of this study was financially supported by the Grant-in-Aid for Scientific Research (C).

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