Effect of gap region medium on acoustic emission wave by single pulse discharge

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Abstract: In this study, the mechanism of material removal in electrical discharge machining (EDM) was investigated by acoustic emission (AE) technique. Twice burst AE wave was detected by optical fiber sensor during single pulse discharge.

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OCIS code: (320.3980) Microsecond phenomena; (320.7120) Ultrafast phenomena

1. Introduction

Electrical discharge machining is high-precision processing technology. Recently, electrical discharge machining (EDM) is widely used for manufacturing various kinds of die and molds. Especially, it is a machining method used for hard metals or those that would be impossible to machine with traditional techniques. EDM is a nontraditional method of removing material by a series of rapidly electric discharges between an electrode and the work piece. Electrical discharge was the sudden and momentary electric current flows. The EDM cutting tool is guided along the desired path very close to the work piece but it does not touch the work piece. Consecutive sparks produce a series of micro-craters on the work piece and remove material along the cutting path by melting and vaporization [1]. The particles were washed away by the continuously flushing dielectric fluid. However, the mechanism of material removal in EDM has not been sufficiently clarified, because discharge is short distance and time phenomenon [2]. In order to clarify the mechanism, acoustic emission (AE) method has been applied [3]. But it is difficult to detect the AE wave during a discharge because of piezo electric sensor is usually affected on electrical noise. In 2001, optical fiber sensor which was not affected on electrical noise was developed in our laboratory [4, 5]. So, this sensor was applied to detect the AE wave during single pulse discharge. In this study, it was investigated that effect of gap region medium on AE wave by single pulse discharge.

2. Experimental setup

Figure 1 shows schematic view of optical fiber sensor system. Laser Doppler Velocimeter (LDV) is used to detect the frequency shift. Light source is He-Ne laser (output power; 1mW, wavelength. λ_0: 632.8 nm), and heterodyne interference technique. An acousto-optical modulator (AOM) changes the frequency of the reference light source from f_0 to

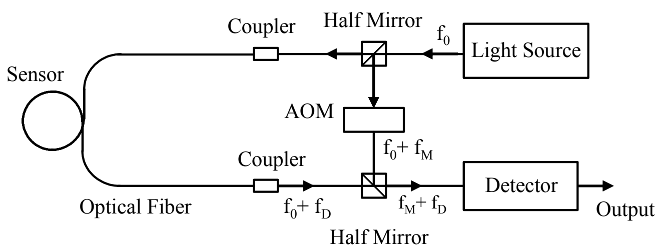

Fig. 1 Schematic view of optical fiber sensor system

f_0+f_M (f_M = 80 MHz) in order to produce beating signals with frequency of f_D+f_M. Optical fibers consist of core, cladding and coating. The core has a higher index of refraction than the cladding, so that total reflection occurs at the core–cladding interface. We used single-mode optical fibers with a coating diameter of 150μm and a cladding diameter of 125μm. The core diameter of the single-mode fiber is small (4.2μm), so we employed single-mode fibers in optical fiber sensor to improve sensitivity. The split light was fed into each sensor and the transmitted light signals were detected using photodiodes. The fiber-optic signals received by the photodiode were transmitted to a PC. Manufactured optical fiber sensors were attached to the surface of the specimens. In order to make several μs discharge duration, condenser circuit was applied. Condenser capacity was changed from 18.8nF to 300nF in order to change discharge duration from 0.5μs to 2μs.The current flowing through the anode is monitored with a current probe (Pearson Electronics, Model-110). The applied voltage was 100V, which is defined by the charging voltage of the capacitor. Discharge interval time was controlled several 10ms by 1MΩ resistance. Figure 2 show the optical fiber sensor. Optical fiber sensor (Radius 8mm, Number of loop 2) was bonded on the aluminum plate. Figure 3 shows the experimental setup. The electrical discharges were made to fall on aluminum (1000 series) plate 400mm * 400mm * 1mm. The optical fiber sensor was located at the center of an aluminum plate so as avoid the effect of reflection of elastic wave. Data acquisition and analysis were carried out with 12 bit resolution and sampling rate of 10MHz.

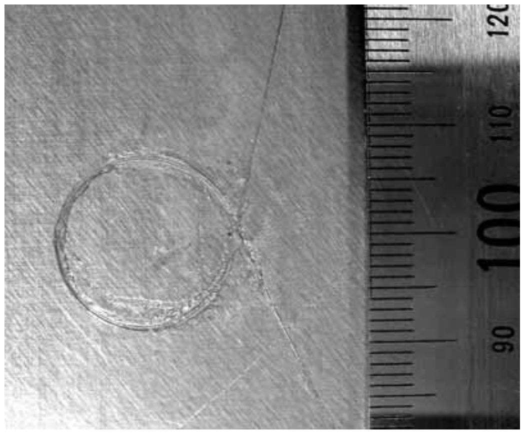

Fig. 2 Schematic view of optical fiber sensor

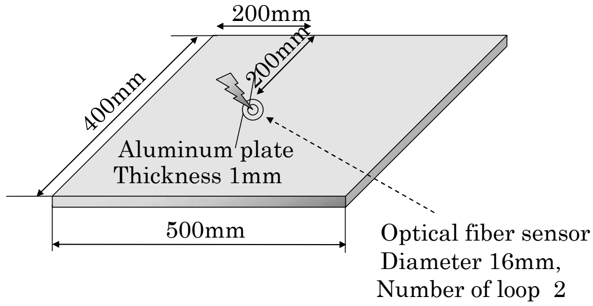

Fig. 3 Experimental setup

3. Results and discussion

3.1 Condenser characteristics Figure 4 shows the typical waveforms of current and voltage signal, when electrode was anode. The current signal goes up 25A and down -4A during 2μs. The voltage goes down from 75V to -20V during 2μs. It was typical behavior of condenser discharge. It is reported that discharge duration is proportional to multiply inductance by condenser capacity of root [6]. Discharge duration is expressed Eq. (1).

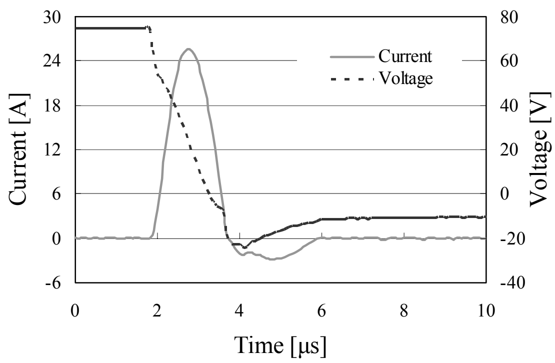

Fig. 4 Typical waveform of the discharge current and voltage

Table 1 Discharge condition

C: Condenser capacity [μF]	τ_p: Pulse duration [μs]	L:Inductance [μH]
18.8×10^{-3}	0.5	1.3
64.8×10^{-3}	1.0	1.6
300×10^{-3}	2.0	1.4

$$\tau_p = \pi (LC)^{1/2} \qquad (1)$$

Where τ_p is discharge duration [μs], L is inductance [μH] and C is condenser capacity [μF]. Relation between discharge duration, inductance and condenser capacity shows Table 1. Condenser capacity increased from 18.8nF to 300nF as inductance was almost constant 1.6μH. It was considered that there were no affect on condenser circuit characteristics. Moreover, we can easily find the time of electrical discharge.

3.2 Effect of gap region medium In order to research the effect of gap region medium on AE wave by single pulse discharge, gap region medium were selected air and oil. Electrical discharge duration was changed from 0.5μs to 2μs. Figure 5 shows the typical AE waveforms detected by optical fiber sensor and current signals. The burst AE wave was detected at 1.7μs after single pulse discharge both in air and in oil. It was the propagation time which longitudinal wave propagates in the aluminum plate. It was found that the burst AE wave was occurred by single pulse discharge. In the case of electrical discharge in air, the burst AE wave was detected only once. Displacement velocity converged on zero after occurrence of the burst AE wave. On the other hand, in the case of electrical discharge in oil, the burst AE waves were detected several times. Displacement velocity did not converge on zero after occurrence of the burst AE wave. Second burst AE wave was occurred between several 10μs and several 100μs. Moreover, it was found that first burst AE wave and second burst AE wave behavior was almost same. It was reported that several burst AE wave was occurred by cavitations [7, 8]. Single pulse discharge was occurred near aluminum plate without direct electrical discharge on the plate.

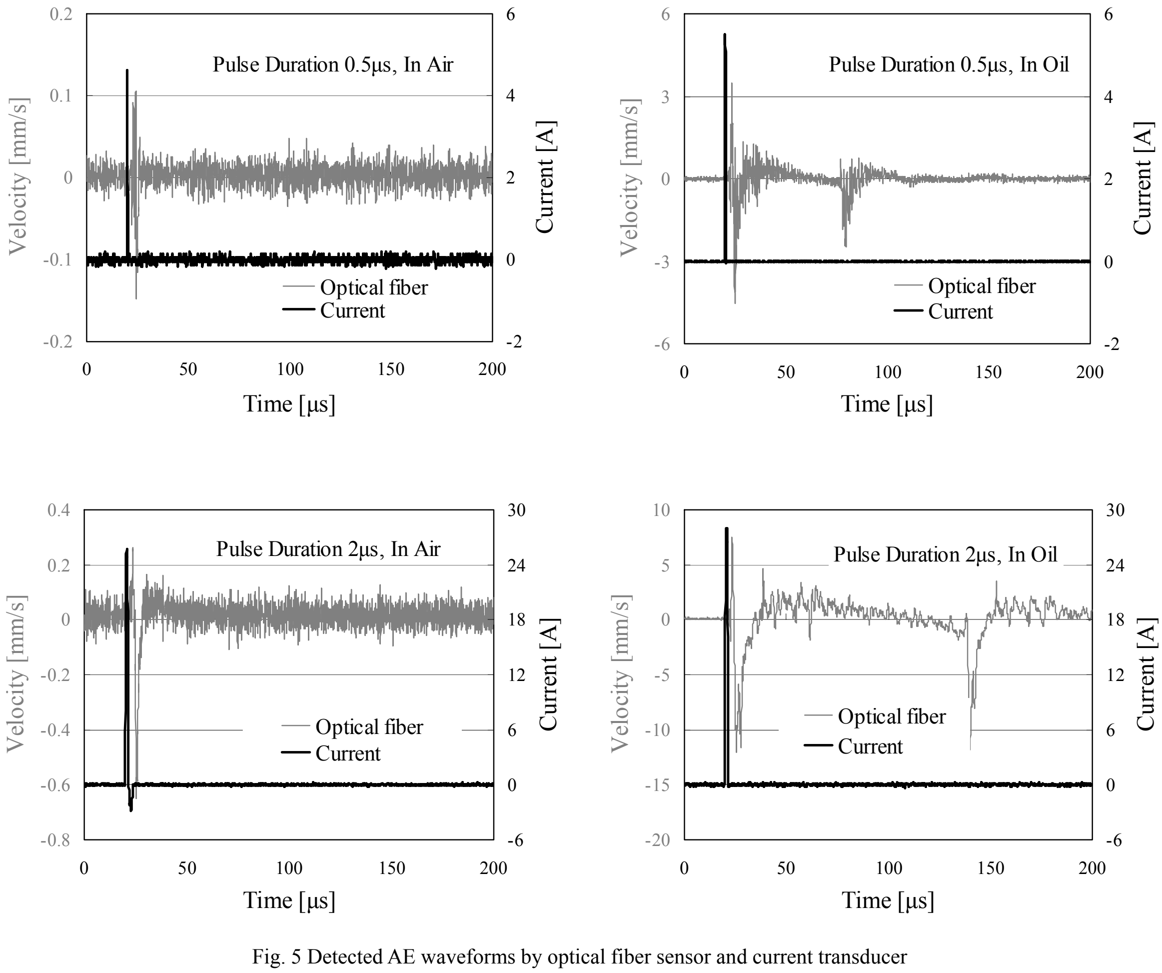

Fig. 5 Detected AE waveforms by optical fiber sensor and current transducer

3.3 Cavitations Figure 6 shows model of experimental setup to detect AE wave occurred by cavitations. Using two cylindrical electrode rods, one was anode and another was cathode, single pulse discharge was occurred near aluminum plate at the center of optical fiber sensor. Figure 7 shows burst AE wave in the case of discharge duration was 2μs. There were several burst AE wave as same as cathode was aluminum plate. Displacement velocity converged on zero after occurrence of the burst AE wave. Second burst AE wave was occurred after 80μs at first burst AE wave. It was considered that the reason of occurrence several times burst AE wave was cavitations behavior.

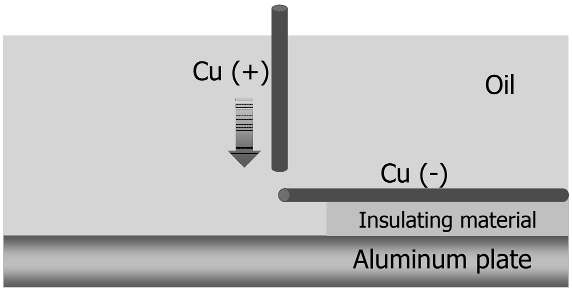

Fig. 6 Model of experimental setup to detect AE wave occurred by cavitations

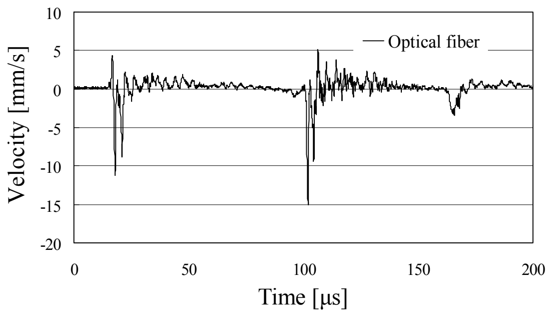

Fig. 7 Detected AE waveforms by optical fiber sensor

4. Conclusion

In this study, it was investigated that effect of gap region medium on elastic wave by single pulse discharge. As the results, it was found that burst AE wave was detected in air and in oil without gap region medium. In the case of electrical discharge in air, the burst AE wave was detected only once. On the other hand, in the case of electrical discharge in oil, the burst AE waves were detected several times. Moreover, single pulse discharge was occurred near aluminum plate without direct electrical discharge on the plate. There were several burst AE wave as same as cathode was aluminum plate. It was considered that the reason of occurrence several times burst AE wave was cavitations behavior.

5. Acknowledgment

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