Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 68 (2018) 96 – 99

www.elsevier.com/locate/procedia

19th CIRP Conference on Electro Physical and Chemical Machining, 23-27 April 2018, Bilbao, Spain

Temperature Measurement of Wire Electrode in Wire EDM by Two-color Pyrometer

Tomohiro Koyano[a, *], Taishi Takahashi[a], Seiya Tsurutani[a], Akira Hosokawa[a], Tatsuaki Furumoto[a], Yohei Hashimoto[a]

[a]*Kanazawa University, Kakuma, Kanazawa, 920-1192, Japan*

* Corresponding author. Tel.: +81-76-234-4711; fax: +81-76-234-4711. E-mail address: koyano@se.kanazawa-u.ac.jp

Abstract

In wire electrical discharge machining (EDM), it is considered that one of the major reasons why the wire electrode breakage occurs is the increase of temperature of wire electrode during machining. This is because the increase of the temperature leads to the decrease in the mechanical strength of wire electrode. However, the temperature of wire electrode has not been directly measured because it is difficult to measure the temperature by conventional measuring methods such as a thermocouple. Therefore, in this study, a two-color pyrometer with an optical fiber was used in order to measure the wire temperature during wire EDM in mist. Experimental results showed that the temperature of the wire electrode could be measured by the two-color pyrometer if the temperature was higher than 100°C. Wire EDM was performed using a mist nozzle, and the temperature measurement of the wire electrode was attempted. Experimental results showed that the output of the two-color pyrometer was not observed, which indicated that the temperature of the wire electrode was lower than 100°C under the experimental conditions used in this study.

Keywords: Wire electrical discharge machining; Wire electrode; Temperature; Two-color pyrometer; Optical fiber

1. Introduction

In wire electrical discharge machining (EDM), it is considered that one of the major reasons why the wire electrode breakage occurs is the increase of temperature of wire electrode during machining [1]. This is because the increase of the temperature leads to the decrease in the mechanical strength of wire electrode. In order to investigate the temperature of wire electrode, the temperature distribution of the wire electrode was analyzed [2, 3]. Takeshita et al. [3] reported that the local temperature at the point where the discharge just occurred was significantly high, 800℃. At another place where the discharge did not occur, the wire temperature was higher than the temperature of the dielectric liquid due to the Joule heating and the heat generated by the preceding discharges. The averaged wire temperature increased with increasing the discharge frequency and the discharge energy. Obara et al. measured averaged wire temperature by measuring the resistance of the wire electrode during machining [4, 5]. Takeshita et al. proposed a method to measure the averaged wire temperature utilizing the sensitivity change of the detection of discharge location [6]. They reported that the averaged wire temperature increased up to 180 °C. Although the methods to assume the wire temperature were proposed, the actual temperature of wire electrode has not been directly measured because it is difficult to measure the temperature by conventional measuring methods such as a thermocouple. This is due to the following reasons: 1) the wire electrode is submerged in dielectric liquid during machining, 2) the diameter of the wire electrode is small, and 3) the wire electrode travels during machining. In this study, a two-color pyrometer with an optical fiber was used in order to measure the wire temperature during wire EDM. This pyrometer is capable of measuring the temperature of the small spot [7, 8]. If the temperature of wire electrode can be measured, the influence of the machining conditions such as material of the wire electrode on the wire temperature can be investigated,

doi:10.1016/j.procir.2017.12.029

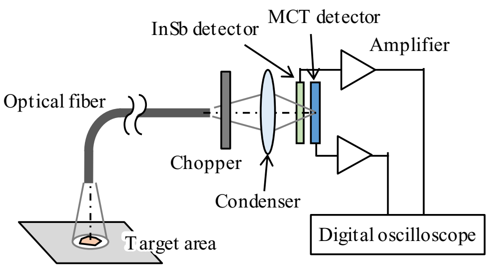

Fig. 1. Two-color pyrometer with optical fiber.

which results in the improvements of wire EDM characteristics. In this paper, the possibility of the temperature measurement of the wire electrode with two-color pyrometer was investigated. In addition, it was attempted to measure the wire temperature during wire EDM using water mist as the dielectric medium.

2. Temperature measurement by two-color pyrometer

2.1 Two-color pyrometer

In order to measure the wire temperature during machining, a two-color pyrometer with an optical fiber was used. Figure 1 shows the equipment of the two-color pyrometer. The pyrometer was mainly composed of an optical fiber, a chopper, a condenser lens (BaF_2), and infrared detectors. It is assumed that the maximum averaged temperature of the wire electrode is below 200 °C [6]. Because the temperature is relatively low, the detectors of InSb and MCT (HgCdTe), which are suitable to measure the low temperature were used. These detectors were mounted in a sandwich configuration, with each detector having a different range of measurable wavelength. The InSb detector responded to incident radiation with a wavelength ranging from 2 to 5µm, while the MCT detector responded to radiation from 5 to 13 µm. The infrared energy radiated from the target object was accepted by a chalcogenide glass fiber with a diameter of 400 µm, and led to the infrared detectors. The output signal of the detector was amplified, and the output voltage of the amplifier was measured by a digital oscilloscope. The temperature of the target object was obtained from the ratio of the output voltage of the detectors. By taking the ratio of the output voltages of the detectors, the influence of the emissivity of the target object can be eliminated.

The calibration of the pyrometer was carried out by measuring the known uniform temperature on a surface of the target material. The target material was brass, which was the same material as the wire electrode of wire EDM. Figure 2 shows the calibration curve obtained by taking the ratio of the output voltages of InSb and MCT detectors. The theoretical curve was calculated from the optical sensitivity of the components of the pyrometer. The experimental results were in good agreement with the theoretical curve.

2.2 Temperature measurement of wire electrode

Because the diameter of the wire electrode used in wire EDM is small, and the averaged temperature of the wire electrode is relatively low, it is considered that infrared energy radiated from the surface of the wire electrode is small. Therefore, the possibility of the temperature measurement of the wire electrode was investigated. Figure 3 shows the experimental method of the wire temperature measurement. The wire electrode was fixed to a zig. The material of the wire electrode was brass with a diameter of 200 µm. Both the wire electrode and the zig were inserted in a furnace, and heated to the set temperature. The temperature inside the furnace was measured by the K-type thermocouple. After the heating, both the wire electrode and the zig were taken out from the furnace. Then, the infrared energy radiated from the heated wire electrode was detected immediately by the two-color pyrometer. Figure 4 shows the output waveforms of the detectors. The set temperatures were varied from 80 °C to 300 °C. Because the optical chopper shown in figure 1 was used, the shape of the output voltage was rectangular as shown in the enlarged view of figure 4(c). When the set temperature was 80 °C, the change of the output voltage could not be observed because of the low energy of the infrared radiation. On the other hand, when the set temperature increased to 100 °C, the change

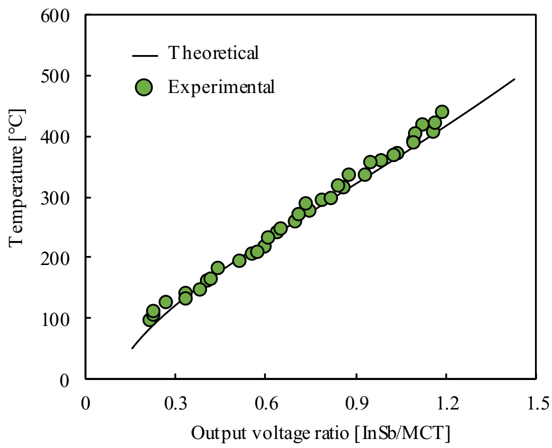

Fig. 2. Calibration curve of two-color pyrometer.

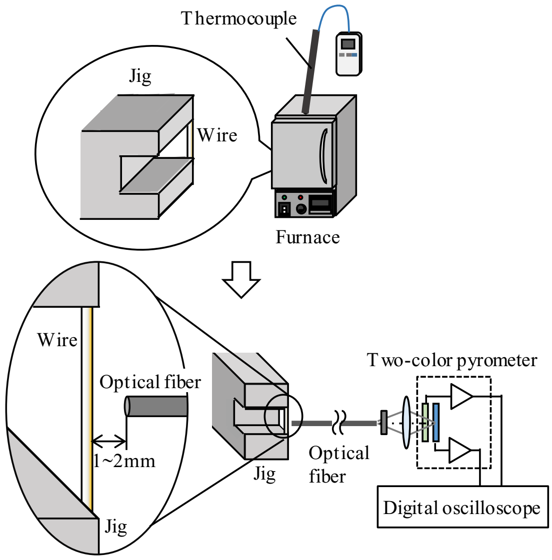

Fig. 3. Measurement of wire temperature.