euspen's 19th International Conference & Exhibition, Bilbao, ES, June 2019
www.euspen.eu

Twin-wire electrical discharge grinding for shaping tapered micro rods

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Abstract
To improve the machining efficiency of tapered micro rods, a new approach of wire electrical discharge grinding with two parallel static wires (TS-WEDG) is proposed. A prototype device for realizing this TS-WEDG method has been developed and preliminary tests have been carried out. With this device, micro rods of both negative and positive taper have been successfully fabricated. The feasibility of the proposed method and its machining strategies have been experimentally verified.

Wire electrical discharge grinding; TS-WEDG; negative taper micro shaft; positive taper micro shaft

1. Introduction

Tapered micro rods find a wide range of engineering applications in the medical and computer, communication and consumer electronics (3C) industries. Examples include electrodes for preventing static electricity or optical fiber welding, and probes for semiconductor inspection, chip engineering and medical equipment. These rods are mainly fabricated by multiple-step grinding which involves relatively long processing times. Therefore, further study for improving the machining efficiency is required.

As a non-contact method operating without any cutting forces, micro electrical discharge machining (micro EDM) offers unique advantages for micro-rod machining. Various researchers have proposed micro electrical discharge machining methods [1-4] and strategies to improve the diameter uniformity of cylindrical micro rods [5]. However, research on processing methods and strategies for fabrication of tapered micro rods is still limited. In this paper, an electrical discharge grinding method with two static wires (TS-WEDG) is proposed for the fabrication of tapered micro rods. The feasibility of the proposed method and its machining strategies are experimentally verified.

2. Principle of TS-WEDG

The schematic diagram of the proposed TS-WEDG method is shown in Fig. 1a-b. Two segments of the same wire electrode are guided by four wire guides to form a narrow slit, through which the micro rod is fed. In particular, the micro rod is fed while rotating along the centerline of the narrow slit and Z+/Z- direction of the machine tool simultaneously. Unlike for the traditional WEDG process [1], the wire electrode is not fed while machining in order to eliminate diameter fluctuations and vibrations of the wire electrode.

2.1. Machining strategies

Two machining strategies can be used to machine tapered micro rods. According to the strategy in Fig. 1c, the wire electrodes are located in the same XY plane, but they are not parallel. Two motion trajectories can be applied by feeding the micro-rod simultaneously along X+ direction and along Z+ or Z- direction. As a result, micro rods having positive or negative taper can be obtained depending on whether the micro rod is fed along Z+ or Z- direction.

Another possibility is to place the two wire electrodes so as they are not in the same XY plane, but parallel if seen in the top view (Fig 1d). Since the two wire electrodes are not in the same plane, the time during which the micro rod is processed by one wire electrode changes. Due to the wear of the wire electrode, the portion of diameter of the micro rod processed by a single wire electrode is larger than the one processed by the two wire electrodes. Therefore, micro rods having a positive or negative taper can be obtained by varying the inclination of the wires in the XZ plane.

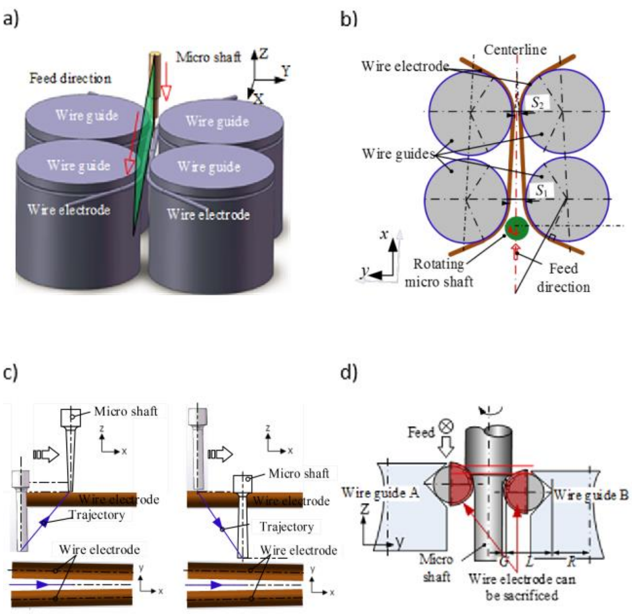

Figure 1. Schematic diagrams of TS-WEDG: (a) perspective view, and (b) top view. Possible machining strategies for machining taper micro rods: (c) and (d).

3. Experimental setup

Fig.2 shows the developed TS-WEDG device. An AJS100-02H adjustment screw was used to adjust the positions of the points S_2 and S_1 (see Fig 1b). It offers 6.35 mm precision travel obtained by a hex-head adjustment (0.254 mm pitch). A displacement reduction mechanism based on a flexible hinge was designed to increase the adjustment resolution. The displacement reduction ratio is about 6. The input-output ratio of the slit gap adjust device is 4.233 degree per micron. A one-dimensional precision positioning stage XA10A-R2H with 2µm full step resolution and 0.5µm backlash is used to adjust the slit width.

The TS-WEDG device was installed on the XY-axis worktable of a SARIX® SX-100-HPM micro-EDM machine. The positioning accuracies of XY-axis worktable and Z-axis spindle are ±2 µm. The experiments were carried out using cylindrical micro rods of tungsten carbide. Before TS-WEDG processing, block electrical discharge grinding (BEDG) was used to reduce the diameter of the micro rods from 300 to 120 µm. A ZEISS® SteREO Discovery V20 microscope was used to measure the dimeter and length of the micro rods after TS-WEDG processing.

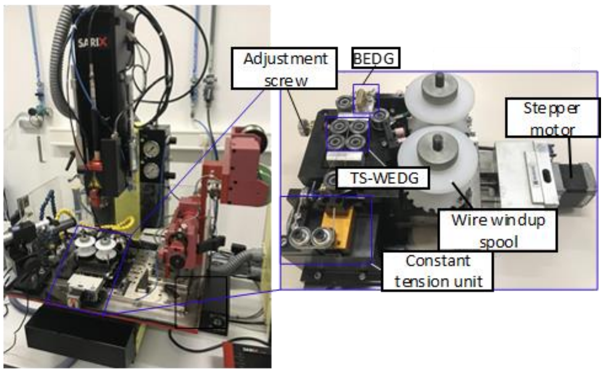

Figure 2. Experimental setup.

4. Results and discussion

4.1. Micro rods with positive taper

Two micro rods with positive taper obtained using the machining strategy in Fig. 1c (feeding of the micro-rod along X+ and Z+ directions) are shown in Fig. 3. The tips of the micro rods have diameters of 13.5 and 16.0 µm respectively. The diameters of the micro rods are uniformly changing. The variability of the taper is due to the fact that different tangential feeding distances were applied. In particular, the micro rod on the left has a larger diameter since the tangential feeding distance was shorter.

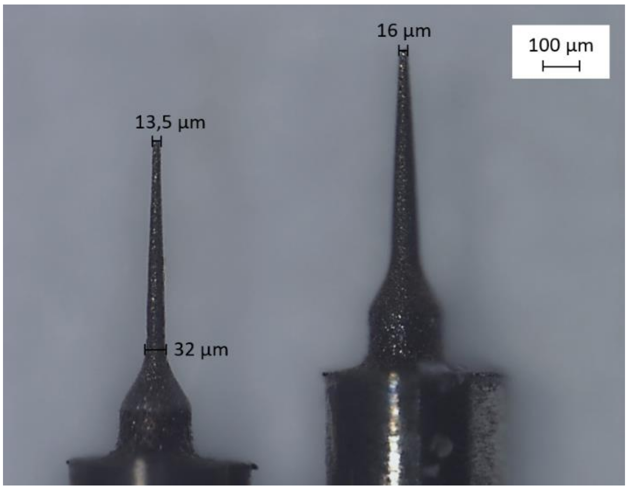

Figure 3. Micro rods with positive taper.

4.2. Micro rods with negative taper

Fig. 4 shows three micro rods with negative taper that were processed by the machining strategy shown in Fig. 1d. The tangential feed distance was varied when machining each micro rod. From left to right, the applied tangential feed distances were 0.5 mm, 1 mm, and 1.5 mm respectively. It shows that the taper of the micro rods increases as the tangential feed distance increases. Therefore, to improve the diameter uniformity of a single micro rod, the tangential feed distance should be reduced.

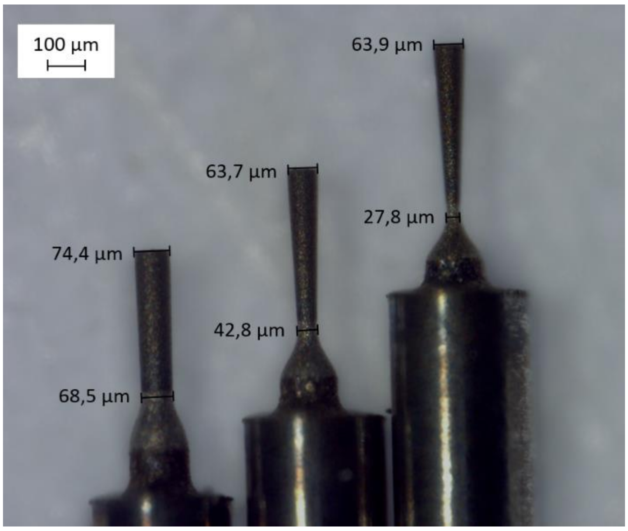

Figure 4. Micro rods with negative taper.

5. Conclusions

In this paper, a method denoted as TS-WEDG is proposed for the fabrication of tapered micro rods in WC. Two machining strategies for machining micro rods with positive and negative taper have been proposed. A prototype TS-WEDG device for implementing this method has been developed. From the experimental results, the following conclusions can be drawn:

1) The proposed method and the machining strategy can be effectively used for producing micro rods with positive and negative taper.
2) The taper of a micro rod increases when increasing the tangential feed distance. A small tangential feed distance should be applied to increase the diameter uniformity.

Acknowledgement

This research work was undertaken in the context of MICROMAN project. MICROMAN is a European Training Network supported by Horizon 2020, the EU Framework Programme for Research and Innovation (Project ID: 674801). The authors would also like to thank the financial support from NSFC (No. 51605323) and Flanders Make covenant dotation.

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