Surface Finishing of Micropins Produced by WEDG

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Abstract

This paper presents a new method of surface finishing for micropin products. Precision micropins thinner than ø100 µm can be produced by WEDG (wire electrodischarge grinding). However, the surface quality of the products is not sufficient for applications that require mirrorlike surface and/or a surface without a heat-affected zone. A succession of two processes, WEDG and lapping, is proposed and tested for its feasibility. In order to ensure the control of the lapping conditions, micropins were WEDGed and lapped on the same machine. The wire electrode for WEDG was used as the lapping tool. A smooth, craterless surface with Ra=18 nm was achieved.

Keywords:

EDM, Micromachining, Surface finishing

1 INTRODUCTION

Microparts of various kinds are now in demand for fabricating high-tech products. In order to supply these microparts, the development of micromachining technology becomes increasingly important. Among the various stages of micromachining, the fabrications of holes and pins are the most basic ones. This paper focuses on the process of making micropins. There are various methods that can be applied for micropin fabrication. However, when a micropin with diameter smaller than 100 µm is to be machined, the choice of methods is rather limited. In particular, when the required aspect ratio is large, i. e., more than five, only a few practical methods are available. EDM, grinding, turning, FIB (focused ion beam) machining and deep RIE (reactive ion etching) are relatively well-known methods. Among them, EDM is the most practical method for producing a high-aspect-ratio, metal/alloy micropin with the diameter of tens of micrometers. Specialized EDM for micropin fabrication, called WEDG (wire electrodischarge grinding) [1], is suitable to produce micropins of various shapes and sizes down to 5 µm in diameter.

There are commercial WEDG machines already available. However, one of the limitations of these machines is that the machined surface has a roughness greater than about 50 nm (Ra) and that the surface is covered with craters. This high roughness and the integration of craters preclude a mirrorlike surface and give rise to the problems of possible high friction and short fatigue life. Therefore, a smoother and/or craterless surface is desired for such applications as shafts for micromotors, mold inserts for optical parts and punches for microblanking. In this paper, the improvement of the product's surface quality is investigated by pursuing the possibility of EDM and by introducing a new process of combined EDM and mechanical polishing. The targeted product size is in the range of 30-100 µm in diameter.

2 FINISHING BY EDM

As mentioned above, WEDG machines are already commercially available. However, the machining conditions recommended or suggested by the maker mainly guarantee high productivity. When the main aim is obtaining good surface quality, there remains the possibility of finding better machining conditions. In this section, some extraordinary conditions are tested as to their effect on the product's surface quality.

2.1 Equipment

The equipment used for the test is a commercial micro-EDM machine with the capability of WEDG. The basic setup of the machine is shown in Figure 1. The relaxation-type pulse generator attached to this machine is configured as shown in Figure 2. The capacitance indicated with dotted lead lines in the figure is not a real capacitor but the stray capacitance between the workpiece (pin) and the electrode (wire). In the finishing operation of our experiments, the capacitor selection switch is set to C_0, the best finishing position, so the stray capacitance acts as the capacitor for discharge. Two resistors are used for charging the capacitor. They separate the cables and parts of the power source from the discharge loop, and

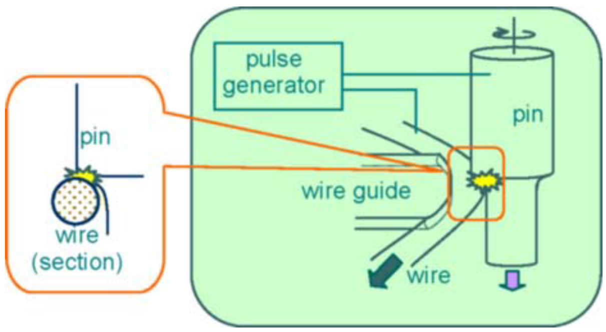

Figure 1: Basic setup of WEDG.

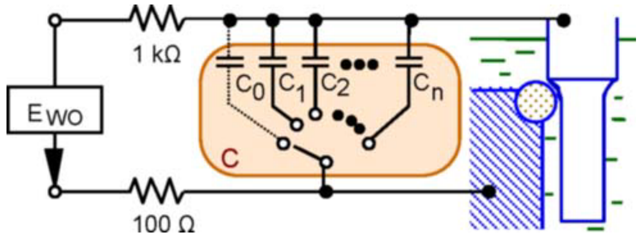

Figure 2: Pulse generator used for experiment.

reduce the influence of extra stray capacitance.

The discharge gap is controlled by feeding back the average value of the current that flows in the discharge loop. A small register (not shown in the figure) is inserted in the loop to detect the current.

2.2 Experimental conditions

Since the demand for pins with diameter less than 100 µm is rapidly increasing, experiments were carried out essentially for pins of ø50 µm. WC alloy was chosen as the workpiece material because of its wear-resistant property that is suitable for tools and spindles.

Conventionally, the best finish is achieved with the capacitor selection of C_0 (stray capacitance), and the open circuit voltage of the wire electrode (E_{WO}) of -80 V relative to the pin.

In the following experiments, voltage E_{WO} was varied in the range of -80 V< E_{WO} <+80 V. This voltage range is not normally used. However, for the purpose of this study, low productivity is not a concern and high electrode wear does not give rise to any problem in WEDG. Therefore, any voltage in the above range is possibly in practice. EDM oil (paraffin) was used as the dielectric fluid. The pin is rotated at about 3000 rpm. The wire slides along the wire guide at the speed of about 150 mm/min.

A ø300 µm pin was first machined to ø60 µm under rough machining conditions (E_{WO}= -100 V, C=220 pF) and finally finished to ø50 µm with the above voltages and the stray capacitance.

2.3 Results of experiment

Figure 3 shows the appearance and the roughness of the surfaces of pins finished with different voltages of -80 V, -40 V and -20 V. The minus symbol means that the polarity is normal (wire: negative).

As clearly seen in the figure, low voltage produces small craters. Accordingly, the surface roughness is lower with smaller absolute values of voltage. Since the roughness value includes the waviness of small pitch caused by various unknown factors, the difference of roughness values between -40 V and -20 V is not obvious.

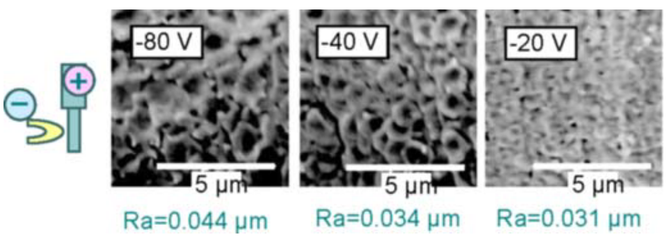

Figure 3: Improvement of smoothness on changing open circuit voltage.

At -20 V, machining tends to be unstable. At absolute voltages smaller than 20 V, for example, -10 V, machining was not possible. We conclude that -40 V is practical for improving the quality of the pin's surface.

Figure 4 shows the result for +80 V. Here the polarity was wire-positive. The result shows that this polarity change is also effective for improving the surface quality. However, with this polarity, voltages lower than 80 V were not practical because machining was not possible. At +80 V, crater size and surface roughness close to those at -40 V were obtained.

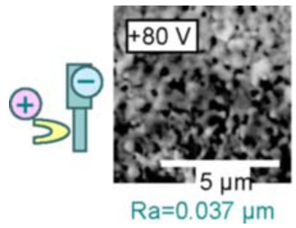

Figure 4: Effect of polarity.

2.4 Summary of EDM finishing

The above experimental results obtained under unusual conditions for reducing crater size can be summarized as follows.

A) Reducing the open circuit voltage in wire-negative polarity is effective for reducing the crater size and surface roughness.

B) Reversing the polarity to wire-positive is also effective.

C) Roughness of approximately 35 nm (Ra) was achieved at the wire voltages of -40 V and +80 V. The condition of lower discharge energy was not practical for either polarity, hence this roughness will be the limit of EDM finishing.

D) The problem of the existence of craters cannot be solved as long as electrical discharge is the removal principle.

3 FINISHING BY LAPPING

3.1 Concept

In order to break through the limitation of EDM process, it is necessary to apply a process based on a different principle of material removal. Abrasive processes, electrochemical processes and FIB machining are some possible methods for this purpose. Considering compatibility with micro-EDM equipment, we chose lapping as the postpolishing method of WEDGed micropins.

In conventional lapping, the flat surface of a lapping pad is pushed onto the workpiece and the abrasive in the slurry introduced between the pad and the workpiece mechanically removes the surface layer of the workpiece. This is quite a different kind of machining from EDM and, therefore, the structure of lapping machines is completely different from that of EDM machines.

The principle of lapping has been analyzed, and the basic requirement of equipment can be summarized as below.

a) Slurry is introduced in the narrow gap between the lapping tool and the workpiece.