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A study on the characterization of high nickel alloy micro-holes using micro-EDM and their applications☆

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Abstract

In this study, the feasibility of fabricating micro-holes in the high nickel alloy using micro-electro-discharge machining (micro-EDM) was investigated. The high nickel alloy is a material with high magnetic permeability. It can be used to shield MEMS prevent interference of the magnetic field. Micro-systems can be assembled and micro-wires can be connected through micro-holes that are drilled in the workpiece. In this way, the internal electronic system can communicate with external system without magnetic wave disturbance. However, since the high nickel alloy is tough and can easily cause cutting tool wear, it is difficult to fabricate micro-holes by the conventional machining methods. In this work, a two-stage cylindrical cutting tool of high hardness was first fashioned. The tool was precisely shaped with a first stage (i.e., tip) having a smaller diameter, and a helically grooved second stage with a larger diameter by the wire electro-discharge grinding (WEDG) process. The first stage of the tool electrode was then used to drill a micro-hole in a plate using micro-EDM process. To improve the roughness of micro-holes, the second stage with helical groove was used for in situ grind machining with SiC particles. Our experimental results show that by optimizing EDM machining parameters, i.e., discharge current of 500 mA, pulse duration of around 4 μs, etc., favorable diameter variation between the entrances and the exits (DVEE), good material removal rate (MRR) and good electrode wear rate (EWR) could be obtained. The addition of the in situ grind machining leads to precise contours, and the surface roughness of micro-holes is reduced to 0.85 μm R_{max}, as revealed by SEM photographs.

Keywords: High nickel alloy; Micro-EDM; MEMS; Micro-hole; Micro-tool; Biomedical analysis

1. Introduction

In recent years, rapid developments in the defense industry, communication systems and micro-electro-mechanical systems (MEMS) have led to significant amounts of research in the field of magnetic interference of MEMS and system with micro-structures including micro-shafts, micro-holes, specially shaped micro-holes and micro-slots. Micro-manufacturing technique has increasingly attracted research interest. Currently micro-holes are formed by different manufacturing methods including micro-EDM, electron beam machining (EBM), laser machining, etching, electric chemical machining (ECM) and micro-ultrasonic machining (MUSM). Due to the different working mechanisms, these methods yield different results [1–12]. Among them, micro-EDM provides advantages such as low-cost apparatus, high aspect ratio of parts, and the capability of fabricating complex 3D shapes. It is therefore potentially suitable for manufacturing micro-holes and micro-parts in miniature devices. Several studies for the micro-hole machining methods have been reported. For example, Allen and Lecheheb investigated the performance of ink jet nozzles fabricated with micro-EDM [1], while Reynaerts et al. demonstrated a micro-EDM machining method that was capable of drilling holes with a diameter of 160 μm and a depth of 380 μm within 2 min [2].

Due to the miniaturization of products, devices become more compact and distances among components are shortened. Magnetic interference among electronic devices thus becomes more severe. Maintaining the quality of products

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while managing the health effects of electromagnetic waves on the human body is an issue of concern. Consequently, shielding materials that prevent magnetic interference have become important. In this study, a new machining method is established and developed to fabricate the required shielding materials.

High nickel alloy (trademark Hymu 80) is a material with high magnetic permeability. It possesses outstanding characteristics of soft magnetic materials including low hysteresis, low eddy-current loss, high magnetic permeability, high saturation and small change in permeability with temperature [3]. These advantages make it an excellent material for shielding against magnetic interference. It is thus used to shield many MEMS components. Micro-holes of precise shape are important in assembling micro-systems and interconnecting micro-wires. This is because micro-holes are needed for micro-wires to make connections between internal and external electronic devices of the system, thus allowing the internal devices to communicate with the outside system while remain shielded from external magnetic interference. However, high nickel alloy is very tough. It is therefore difficult to drill micro-holes by traditional machining methods. In this study, a new machining method that combines micro-EDM process using the first-stage of the tool electrode and an in situ grind machining process using a helically grooved second-stage of the same tool electrode is proposed to fabricate the high precision micro-holes in high nickel alloy. Since the first-stage and second-stage tool electrodes are formed as a single-piece coaxial machining tool, there is no need to dismount during the whole process, micro-holes with high degree of roundness can thus be formed.

2. Experiment

The experimental set-up is shown in Fig. 1. The experimental equipment includes an EDM machine, a WEDG mechanism and a four-axis controlling system. The WEDG mechanism is fixed on the EDM worktable. The four-axis control system is fixed onto the EDM machine head, on which the linear guide can be moved in the forward/backward and left/right directions by motors *Y*, and *X*, respectively. The micro-tool is clamped in a vertical chuck and can be rotated by motor *C*, and it can be moved up and down by the EDM main spin motor *Z*. The motion resolutions of motors *X*, *Y* and *Z* are 0.5 μm, 0.5 μm and 1 μm, respectively.

2.1. Materials

The high nickel alloy is composed mainly of Ni (79 wt%) and Mo (4 wt%). It exhibits high magnetic permeability, a high saturation value and a small change in permeability with temperature. These advantages make it an excellent material for shielding against magnetic disturbance. For example, it

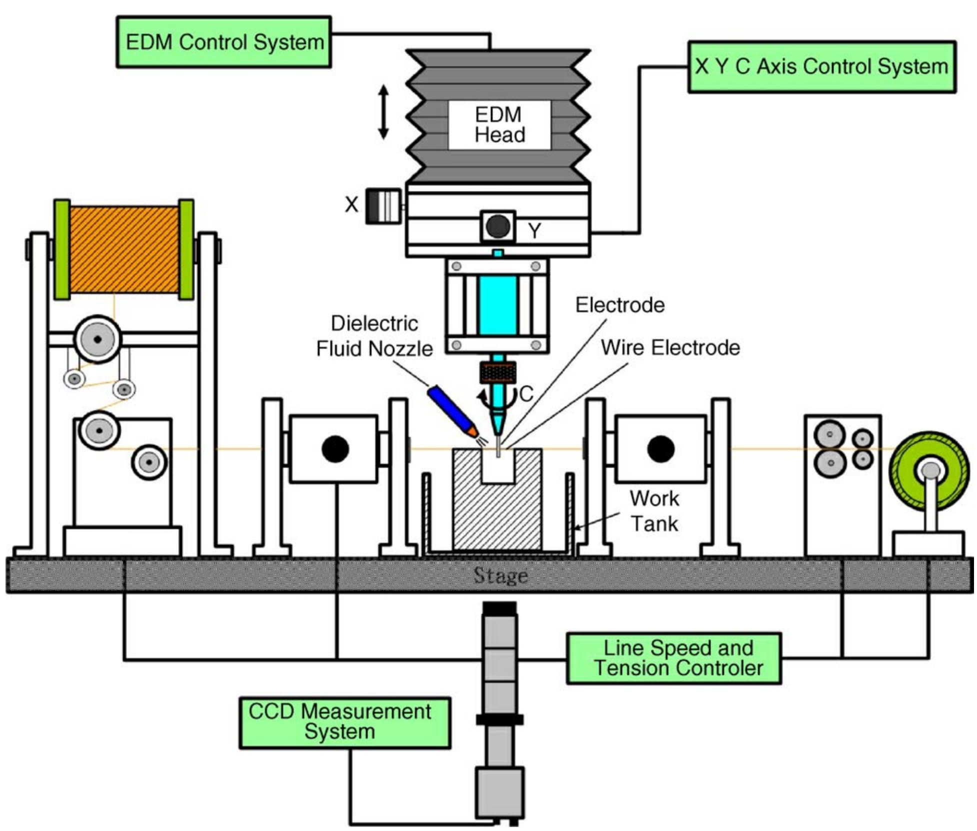

Fig. 1. Configuration of WEDG and micro-EDM apparatus.