

Research Article

Fabrication of Micro Textures using Aluminium and Copper tool Electrode by EDM

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Abstract: There is a growing demand for industrial products not only with an increased number of functions but also with reduced dimensions. Since the miniaturization of industrial products has been a trend in technological development, micromachining is expected to play an increasingly important role in today's manufacturing technology. Micro-machining based on lithography has many disadvantages, unlike tool-based micro-machining technology, such as micro-turning, micro-grinding, micro-EDM, and micro-ECM, which have many advantages in productivity, efficiency, flexibility, and cost-effectiveness. Micro-machining is the most basic technology to produce such miniaturized parts and Micro-textures. In the current study, an attempt has been made to develop a tool electrode from aluminium and copper and to assess their feasibility for creating microtextures on the surface using the EDM process.

Keywords: EDM, Micro-EDM, Electrodes, Electrode material, Texturing.

1. Introduction

Recent studies emphasize EDM's suitability for machining hard materials like Titanium Grade 2, with advanced modeling enabling better understanding and optimization of machining parameters.

Comprehensive reviews reveal EDM's evolution toward high-precision, sustainable manufacturing, highlighting innovations in tool materials, dielectric materials, and control strategies.

1.1 Micro-EDM

Micro-EDM (Electric Discharge Machining) is a non-conventional machining. It is potentially an important process for the Fabrication of micro-tools, micro-components, and parts with micro-features. The main advantages of the micro-EDM method are its low setup cost, high accuracy, and large design freedom. There are different conventional and non-conventional methods to obtain microstructures, such as photography, injection molding (using a micro-mold cavity), turning, milling, and grinding with a single-point diamond cutter or a very fine-grit grinding wheel, but all these methods are either very costly or difficult to implement.

1.2 Micro-Texturing

Surface micro-texturing deals with the issues pertaining to various fields of engineering for enhancing essential functions such as tribological, wetting, biocompatibility, sustainability, cleanliness, etc. Among all the aforementioned sectors, micro-texturing of curved/free-form large areas is getting huge attention, e.g., micro-textures on artificial biomedical implants



enhance sustainability and life cycle by better implant-tissue interface, cell-adhesion, and cell proliferation. Due to growing awareness of the significance of micro-texturing, significant thrust is now being given to innovations that employ surface textures on freeform/curved surfaces.

1.3 Working Principle

Electric Discharge Machining is a process of obtaining a microstructure. Figure 1 shows the basic schematic of the EDM Process. It is a process based on electric discharge between two electrodes, i.e., the tool and the workpiece [1-8]. A dielectric medium separates the tool and workpiece, either dielectric oil (e.g., transformer oil, paraffin oil, kerosene, or lubricating oil) or deionized water. For releasing an electrical discharge, a voltage is applied between the tool and the workpiece, and the distance between the electrodes is decreased. By reaching the breakdown voltage of the dielectric medium, a discharge takes place, establishing a plasma channel which causes a current flow. Thus, temperatures of more than 10000 K occur, and the material gets melted and evaporated, creating an expanding gas bubble. Stopping the energy input leads to a collapse of the plasma channel and, consequently, to the end of the discharge. The formed gas bubble collapses, too. Thus, results in the removal of material from the required area. The particles of the removed material are flushed away by the flowing dielectric medium. By applying a voltage between the tool and the workpiece again, the process repeats in the same procedure.

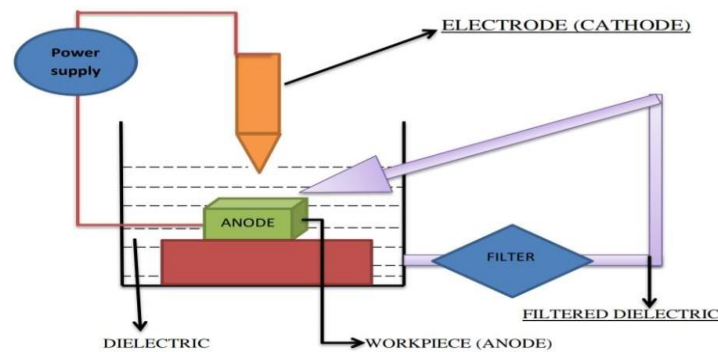


Figure 1: Schematic of EDM

1.4 Electrode Material

EDM electrodes should be highly conductive and are erosion-resistant materials, such as graphite or Copper. EDM is a process that uses a controlled electrical spark to erode materials. EDM electrodes include components made from brass, Copper, Copper alloys, graphite, molybdenum, silver, and tungsten.

When selecting EDM electrodes, the most important consideration, alongside their form and function, is the material's conductivity and its erosion resistance.

- Conductivity promotes cutting efficiency, since electric current is the “cutting tool”.
- Erosion resistance (a factor of melting point, hardness, and structural integrity) gives the electrode a longer service life and lowers the frequency of replacement. These properties, which vary almost exclusively by the type of alloy or material used, must be the deciding factor when selecting an electrode.

The electrode tool material is very important for high aspect ratios due to the critical tool wear problem. As per our literature review and study, we came to the decision of using a different material that has not been used till now. After discussing with our supervisor, we decided to use Aluminum and Copper.

Aluminum is a good electrical and thermal conductor, lightweight, has high melting and boiling points, is corrosion-resistant, has high ductility, is easily available, affordable, etc. Commercially, it is seen that pure aluminum is soft. It is strengthened when alloyed and tempered. Generally, it is alloyed with copper, magnesium, manganese, silicon, tin, nickel, and zinc.

Copper is a reddish metal with a face-centered cubic crystalline structure. It reflects red and orange light and absorbs other frequencies in the visible spectrum, due to its band structure, so it has a nice reddish color. It is malleable, ductile, and an extremely good conductor of both heat and electricity.

2. Literature review

Research papers that we have studied related to this topic mainly focus on the potential of macro and micro EDM in the machining industry, their applications, such as texturing, machining hard materials, etc. [9]. Sushil Kumar Choudhary et al carried out a study on micro-EDM in which they studied the process EDM, process parameters, performance parameters, applications, etc, and came to the conclusion that Micro-EDM is an excellent process for fabricating micro parts on hard-to-machine and multi-materials with high accuracy and surface quality [10]. Gurule et al. discussed the potential of Micro-EDM extensively based on previous and recent research on Micro-EDM [11]. Jahan et al investigated the surface finish using μ -EDM of WC with tungsten (W), copper tungsten (CuW), and silver tungsten (AgW) electrodes. It was established that the AgW electrode produces a downy and imperfection-free nanosurface with the lowest surface roughness among the others. CuW electrode achieved the maximum MRR. Silver tungsten appeared best suited for producing smooth, shiny, and high surface finish with a negligible amount of defects on the surface during the micro EDM of tungsten carbide [12]. Tzu-Wei Huang et al. used the notch cross-section shape micro electrode tools made by WEDG technology to drill a micro hole in a tungsten carbide workpiece. Compared to the cylinder micro electrode tool, the rotating single-notch and dual-notch cross-sections generate different flow fields. The single-notch micro tool caused more upward flow than the others. Due to which upward flow, the debris removal rate was improved [13]. Eckart Uhlmann et al used different tungsten carbide materials for the electrode and came to the conclusion that there is a correlation between the material characteristics of the different tungsten carbide-cobalt grades and the S-EDM process behavior regarding material removal rate and relative tool wear. Higher cobalt contents and grain sizes also improve the material removal rate. The generated relative tool wear of the tungsten carbide material is inferior compared to copper E-Cu58 and graphite EDM-3 [14]. Hideki Takezawa et al. used 1 and 3 mm normal pipe electrodes and grooved pipe electrodes for improving machining speed and stabilizing discharge state, and concluded that straight groove electrodes had a large number of normal discharges compared with the normal electrode. It was assumed that the stable discharge state continued owing to the increased removal of machining debris when the groove electrode was used.

3. Experimental Setup

3.1 Process for development of EDM electrode tool

The size of the tool electrode used in micro-EDM is small, and hence, Fabrication and handling of the tool are quite difficult. Conventionally, micro tool electrodes are fabricated by Wire electrical discharge grinding (WEDG) or block discharge grinding (BEDG) methods [15]. Wei Han and Kunieda et al machined micro rods with electrostatic induction feeding. H. Onikura et al. employed ultrasonic vibration-assisted mechanical grinding to fabricate high aspect ratio micro tools in cemented carbide [16].

We have fabricated the tool on a CNC lathe machine and tried to reduce the diameter of the pointed tip as fine as possible using the CNC. The processes involved normal turning and taper turning. The tool was fabricated from a cylindrical rod of aluminum and Copper to the required length.



Figure 2: Al tool electrode (Tip Dia.- 0.5mm)



Figure 3: Cu Tool Electrode (Tip Dia- 0.15mm)

3.2 Micro-EDM Process

The EDM process was conducted on a ZNC 250 EDM machine, ECOLINE, on workpieces made of tool steel. The dielectric oil used was EDM oil IPOL SEO 450, which is a high-performance spark erosion oil manufactured using high-quality, low-aromatic, specially selected hydrocarbon base stocks. It is formulated with an ideal viscosity to provide an effective EDM operation with minimum electrode wear. They are virtually colorless, and low aromatic content promotes low odor and low fume generation. In the EDM process for creating texture depth, a minimum was kept, which can be achieved by the machine, i.e, 0.02mm, keeping the input current at 1Amp and pulse rate 150 microseconds. At first, an aluminium tool was used on a test workpiece to check the feasibility of the EDM process using an aluminium tool. Similarly, the copper tool was used for the EDM process.

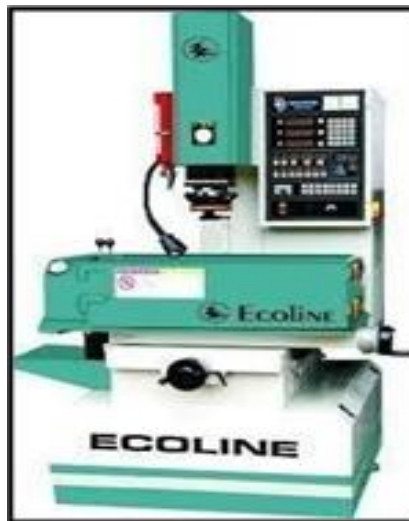


Figure 4:EcolineZnc 250 EDM machine (Source: www.tradeindia.com)

4. Results and Discussion

4.1 Micro-Texturing through the Aluminum Tool

The results of texturing using an aluminium tool electrode were not promising, as after one micro hole, the tip of the tool eroded. This might be due to its relatively low melting point, which prevented it from withstanding the high temperature of the spark. From this, it can be concluded that Aluminium is not a good choice of material for EDM tool Electrode, as its tool

wear rate is very high, and the process of EDM was not efficient with Aluminium electrode. The wear of the electrode tip of the tool is shown in Figures 5 and 6 below.



Figure 5: Al Tool before EDM process



Figure 6: Al Tool after EDM process

4.2 Micro-Texturing through Copper Tool

The results of texturing using a copper tool electrode were kind of successful because we successfully made multiple smaller depth holes with very little electrode wear, which shows that using a copper tool for creating textures will be feasible. We have created holes in a circular pattern using the EDM process, which is shown below in Fig. 7.



Figure 7: Cu Tool Before EDM



Figure 8: Cu Tool after EDM



Figure 9: Textured Pin (Workpiece)

5. Conclusion

The results presented in this study and from the literature review done, it can be concluded that EDM can be successfully used as a micro-fabrication technique to produce micro

parts and micro textures. It can be noticed that holes down to the size of a micrometer can be manufactured using micro EDM. In this study, we studied various methods for micro EDM tool fabrication and materials that can be used for this purpose. We proposed using aluminum and copper as a material for the development of an electrode tool for micro-texturing on the workpiece. From the results we have seen, aluminum, when used for EDM, results in a high Tool wear rate, which was not efficient, but copper has a very low wear rate as compared to Aluminum, which makes copper an efficient material for micro-EDM or texturing. In the end, we can say that Aluminum is not suitable for the process of Micro-EDM due to being inefficient and should not be used.

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