

A REVIEW OF ELECTRICAL DISCHARGE MACHINING (EDM) WITH RESPONSES

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Abstract:

High precision items are manufactured in industry using the non-traditional, non-contact electro discharge machining (EDM) technology. Since EDM can melt any electrically conductive material regardless of hardness, it is well recognized for cutting hard and brittle conductive materials. The work piece produced by EDM is influenced by the materials' melting points, electrical resistance, and thermal conductivity. The tool is suitably submerged in a dielectric liquid, such as kerosene, deionized water, or any other appropriate fluid, as does the work piece. This study offers a significant overview of several EDM operation types. The machining reactions and mathematical modeling are also briefly discussed.

Key Words: WEDM, Micro-EDM, Non-Conductive Ceramics, TWR, MRR

Introduction:

The industry uses the non-traditional and non-contact electro discharge machining (EDM) technique to produce high precision products, particularly in the manufacturing, aerospace, automotive, communication, and biotechnology sectors [1-7]. Due to its ability to melt any electrically conducting material, regardless of how hard it is, EDM, as seen in Figure 1, is well renowned for its ability to machine hard and brittle conductive materials [4-5]. A form of thermal machining called EDM uses the heat energy produced by an electrical spark to remove material from the work piece [6-8]. Thermal conductivity, electrical resistance, and melting temperatures of the materials all affect the work piece produced by EDM [9-11]. Between a micro-sized tool electrode and the work piece material, a fast succession of electrical sparks or discharges take place over a brief period of time inside a continuous spark gap. Sparks have a repeated and distinct character. A suitable fluid such as kerosene, deionized water, or any other acceptable dielectric media is used to sufficiently submerge the tool and the work piece [12-14]. A soft and easily machine able electrode material may be used to machine a very hard, delicate, or thin work piece due to the process's non-contact nature and practically force-free machining [15-17]. Mechanical strains, clatter, and vibration issues during machining may therefore be reduced as a result of its non-contact nature [18]. In-depth analysis of the various EDM operation types is provided in this work. The machining reactions and mathematical modeling are also briefly discussed.

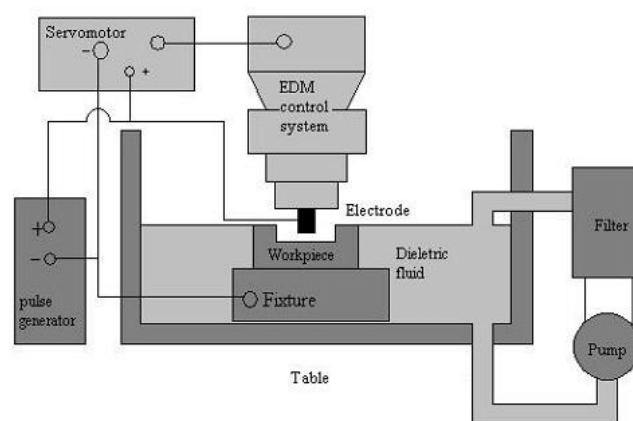


Figure 1: Schematic diagram of EDM

Types of Electro Discharge Machining:

Electro Discharge Machining (EDM) is a precision machining process that uses electrical discharges to remove material from a work piece. There are several types of EDM methods, each with its own variations and applications. Here are the main types of EDM:

Wire EDM:

This is one of the most common types of EDM. It uses a thin wire electrode to cut through the work piece, creating a desired shape. Wire EDM is highly accurate and is often used for making intricate and precise parts, especially in the aerospace and medical industries. Wire electrical discharge machining (WEDM) was introduced because it has the ability to cut intricate shapes and extremely tapered

geometries with high performance especially in precision, efficiency, and stability [5, 22, 23]. The material removal technique for WEDM and EDM operations is quite similar, with the exception that WEDM employs winding wire as an electrode. [5, 6, 24].

Micro-EDM:

EDM operation has previously been established in microscale industries, where the surface of the work piece may be machined with no deviation or breakage thanks to sensitive microtools. The same basic tenet underlies conventional EDM technology and micro-EDM. A single discharge using an RC-pulse generator demonstrates that the current and voltage are not kept at any certain level. However, the RC-pulse generator depends on the capacitor's current state of charge. Since it can generate a very tiny quantity of discharge energy, the RC-pulse circuit type is known to have a low material removal rate (MRR). Micro-EDM is specifically designed to produce parts with dimensions between 1 and 999 μm . Therefore, micro-EDM is a suitable method of machining to make high precision and high accuracy micro geometries goods [26–29].

EDM of Non-Conductive Materials:

EDM may be used to prepare materials with a minimum electrical conductivity of 0.1 Scm^{-1} . Therefore, materials such as metals and conductive ceramics can go through this procedure [30–32]. Since ceramics are challenging to process using traditional cutting techniques, researchers are employing EDM and micro-EDM [33, 34].

However, the ceramics must be conductive in order for the machining process to be continuous. As a result, one possibility is to add dopants like titanium nitride (TiN) or tungsten carbide (WC) to the ceramic to make a composite. Another option is to embed the ceramic particles in a metal matrix to produce a conductive composite. Utilizing ultrasonic aided spark erosion is another strategy. The spark erosion and fracture development brought on by the ultrasonic energy might result in spalling. [10, 31, 32]

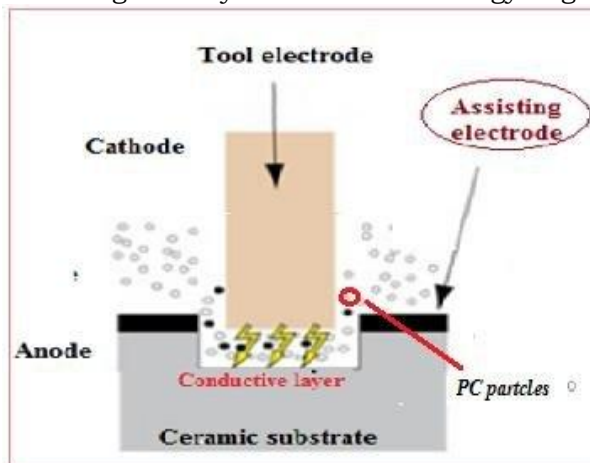


Figure 2: Schematic diagram of micro-EDM of non-conductive ceramic

Dry EDM:

To remove the debris from the machining gap during the EDM process, dielectric fluid is crucial. Additionally, the dielectric fluid aids in enhancing the quality and economy of the machined components as well as the efficiency of the machining process. Mineral oil-based liquids or hydrocarbon oils, which pose a fire risk and have negative environmental effects, are the most often utilized dielectric fluids. This is due to the extremely hazardous and non-recyclable nature of the dielectric wastes produced during the machining process. In addition, the chemical breakdown of mineral oils at high temperatures during machining produces hazardous gases (CO and CH₄). The machining operators are also at risk for health problems from the hazardous vapors [24, 41–45].

Dry EDM (Figure 3) is an environmentally friendly machining technique where the electrode is in the shape of a pipe and gas or air, rather than liquid, is utilized as the dielectric fluid to cool the cutting surface and remove debris from the gap [18–22].

In dry micro-WEDM, as opposed to traditional WEDM, the vibration of the wire electrode, smaller gap distance, and extremely minimal process reaction force help this method to enable great precision in cutting off the desired shape. Dry EDM milling results in higher machining speeds and reduced electrode wear ratios. Dry EDM milling may be used to create three-dimensional (3D) surfaces out of cemented carbide [23, 42]. When the tool is in rotation or planetary motion, the machining operation stability is maintained [33]. Dry EDM has a low electrode wear ratio because the reactive force only little physically harms the tool electrode. This is so that when a discharge occurs, there is no evaporation of liquid dielectric fluid in the dry EDM. Additionally, the electrode wear is decreased by the adherence of machining waste to the electrode [31].

Machining Responses:

Material Removal Rate (MRR):

When close tolerance components are necessary for items like tools, dies, and molds for press operations, plastic molding, and die casting, dimensional precision becomes crucial when it comes to

EDM. MRR has therefore been one of the primary issues. The weight of material removed from the work piece throughout the course of machining time is used to express the MRR. To estimate MRR, several academics have tried to create empirical models. The MRR is affected by the frequency of the discharge, the work material, the electrode material, the polarity, the amount of pulsed current in each discharge, and the state of the dielectric cleansing. [12, 24, 27].

Some researchers disagree on the micro-EDM's material removal technique. This occurs as a result of some aberrations from the basic process mechanism. Micro-EDM is still frequently utilized in industry for high-precision machining of conductive materials, despite the fact that there are numerous unknowns surrounding the mechanism of material removal. Regardless of their hardness, Micro-EDM can remove materials in the sub-grain size range (0.1–10 μm) [41].

Tool Wear Rate (TWR):

Tool wear rate is a critical parameter in machining processes and manufacturing. It refers to the rate at which a cutting tool, such as a drill bit, end mill, or lathe tool, undergoes wear or degradation during the machining of a work piece. [8,21,24]. Tool wear is a natural and unavoidable occurrence in machining due to the mechanical and thermal stresses involved. Understanding and controlling tool wear rate is essential for maintaining product quality, achieving efficiency in machining operations, and prolonging the tool's lifespan [20-26].

Mathematical Modelling:

Numerous researches have been done on the creation of an empirical model using parametric analysis of the micro-WEDM parameters. Material removal rate (MRR), over cut, kerf, and surface roughness were used as performance indicators, while gap voltage, capacitance, and feed rate served as control parameters. Through simulation, the ideal parametric parameters were found. The integration of links between output performance and controllable input characteristics may be effectively done through modeling. In this overview, a few instances of mathematical modeling are presented. One example of a mathematical model for vibration in micro end milling is Eqn (1), which uses Taguchi as the design and ANOVA for the analysis [73]. As for Eqn (2) and (3), shows the mathematical model of hardness and MRR of non-conductive zirconia using micro-EDM [38].

$$V = 65.94 + 2.13 \times 10^{-3}n - 0.99f + 1.73 \times 10^{-3}d - 6.84 \times 10^{-5}nf - 1.93 \times 10^{-3}nd + 1.01fd \dots\dots\dots (1)$$

Where; V is average vibration, n is spindle speed (rpm), f is feed rate (mm/min), d is depth of cut (μm).

$$H = 9201.15 - 62n + 16v + 0.15n^2 - 0.05nv - 1 \times 10^{-4}n^3 \dots\dots\dots (2)$$

Where, H = hardness (Hv), n = rotational speed (rpm), v = gap voltage (V).

$$\text{MRR} = -101.7 + 1.9n - 2.93v - 4.36 \times 10^{-3}n^2 + 0.012v^2 + 1.1 \times 10^{-3}nv + 3.1 \times 10^{-6}n^3 \dots\dots\dots (3)$$

Where; MRR = material removal rate ($\mu\text{g}/\text{min}$), n = rotational speed (rpm), v = gap voltage (V).

Conclusions:

The EDM process is a versatile machining procedure that can create intricate three-dimensional (3D) forms, which is particularly useful in the industrial, aerospace, automotive, communication, and biotechnology sectors. It is renowned for its ability to machine fragile, hard conductive materials. The work piece and the tool are both properly submerged in a dielectric liquid. This study offers a significant overview of several EDM operation types. A brief discussion is also done on the machining responses and mathematical modelling. This reviewed paper summarizes that:

- WEDM can perform well when cutting highly tapered geometries and complicated structures.
- Micro-EDM is a technique created to produce small-scale components with extreme accuracy and precision.
- Non-conductive ceramics that are EDM-machined employing the assisting electrode method (AEM), which results in novel enhanced ceramic structure without geometrical variety.
- Dry EDM is a method in which gas rather than liquid is employed as the dielectric fluid. In order to produce a steady machining process, it is a method that necessitates some change throughout the machining operation.
- In order to accomplish maximal material removal with high accuracy and precision components, machining responses like kerf and MRR are crucial.

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