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A Review of the Effects of Various Electrode Materials in Electrical Discharge Machining

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Abstract

Electrical discharge processing (EDP) is a non-traditional machining technology that removes materials using spark erosion. Tools, also known as electrodes, are a precise regeneration of machined forms or compartments with specified processing tolerances, and the process is overqualified because the electrode is a critical component of the processing process, affecting the rate of material and tool removal. Acknowledge and bring. The electrode parameters are chosen considering a variety of factors, including tool material, cutting rates, and the dielectric environment. This article examines several electrode materials and their influence on the electrical discharge processing process.

Keywords: EDM, MRR, TWR, Electrode Material.

1. Introduction

In recent years there have been major developments in new high-tech and thermal equipment compared to other conventional building materials. With the development of these solid and durable materials the conventional mechanical system does not work properly on a machine. The mechanization of these new solid and durable materials is made up of many unusual mechanical manufacturing processes. Of these several unusual mechanical systems EDM (Electric Discharge Machining) is one of the most widely used in internationally recognized operating systems.

An electric discharge machine is a machining process that uses electric discharge to remove material from the workpiece. The workpiece and tool electrodes are connected to the positive and negative terminals of the power supply, and the dielectric flows between the tool and the workpiece within the specified spark gap. The dielectric and sparks form to remove material from the workpiece [1]. Because the electrode materials used in the machining process influence the rate of material removal, tool wear, and surface roughness of the completed workpiece material, the electrode material selection procedure should be exhaustive [2]. Various electrode materials have been utilized in EDM over the duration of the electrical discharge processing process. machining in the several year electro-discharge machines has been applied to machine intricate shapes and hard to machine work [3].

2. EDM process

Electrode discharge machining (EDM) removes material by igniting small, intermittent sparks between the electrode and the workpiece. Electrode and component are typically cathode/anode. Electro- erosion is the breakdown of the electrode material into any type of discharge, typically through gases, liquids, or in certain circumstances solids, which is the electro- erosion effect. For an electrical discharge to occur, dielectric molecules must be broken down into ions and electrons. Servo motor, workpiece, dielectric medium, and a tool make up the majority of the discharger's components. Direct electricity is provided to the section and tools. Sparks of 0.005 to 0.5 volts are formed during the processing of electrical discharge. It is possible to generate discharge breakdown and emission of electrons from an electrode when the dielectric is not a power cord and is subjected to the suitable pressure and voltage during the sparking period. Ionization occurs at a spark distance. The electron current from the pole to the anode travels at an extremely high rate with each discharge or electric spark, causing significant shock waves in the room and on the electrode surface. When this happens, the temperature of the substance increases sufficiently to melt some of the material. The molten metal particles are pulled away from the part by the electric field force created by the spark. A compressive force generated by the electric and magnetic fields is responsible for slowing down metal removal when a workpiece is connected to an anode and a tool is attached to a cathode.

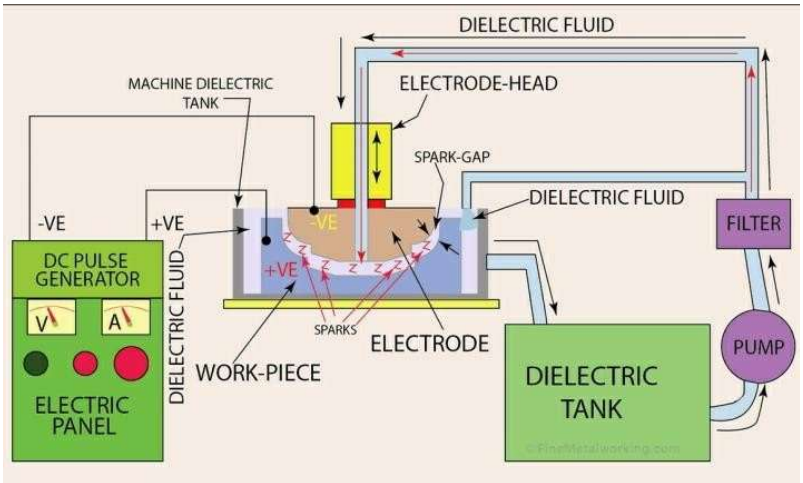

Figure1: - EDM Machining Process

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Electrode materials used in electro discharge machining

Graphite, copper, brass, copper-tungsten, and other electrode materials are commonly employed [4]. They should be able to meet the following requirements:

An electrically conductive substance is needed. Temperature rise and tool wear can be minimized by using thermally conductive electrode materials. To reduce tool wear, the high-density electrode material is preferred. The melting point of the electrode material must be high. To be cost-effective and easy to produce, it must be simple to make. Brass is a copper- zinc alloy. They are used to fabricate small tubular electrodes and electro-discharge (EDM) wires. Brass is less durable than copper or tungsten, but it is easier to produce for applications by die casting or extrusion. It can be utilized in Wire EDM since new wires are continuously supplied during machining. Copper and its alloys are stronger than brass alloys, although they are far more difficult to work with than graphite or brass. In terms of electrode materials, copper has a desirable quality, although it is more expensive than graphite. In addition, the high resistors allow it to be employed in machines that require materials or tungsten carbide materials with high ends. Copper tungsten materials are alloys of tungsten and copper. These synthetic materials are made via powder metallurgy and are quite expensive when used with any electrode material. However, they are extremely beneficial for producing deep tooth decay in areas where dielects from tungsten carbide are not suited. Graphite is utilized when the room must be machined at low rates, as graphite has an excellent cleaning effect at low speeds. It is less expensive than other electrode materials but lacks the intensity of copper or an alloy. Molybdenum is used in EDM wire to create narrow slots with exceptionally small corner radius requirements because it is pliable and easily moulded into wire; it also has high tensile strength and is an excellent conductor of electricity. Silver Tungsten material is composed of scattered tungsten carbide particles in a silver matrix. Silver is chosen because it is highly conductive, whereas tungsten is highly corrosion resistant. Additionally, tungsten has anti- welding capabilities. This mixture is utilized in applications that require a high level of electrical conductivity. Tellurium can outsource as brass and is higher than pure copper, so it is used in applications that require a good ending.

3. Literature Review

Influence of Different Tool Electrode Materials on EDM is the title of a work written by S. Dewangan, C.K. Biswas, and S. Gangopadhyay. A study investigated the surface integrity of AISI P20 tool steel. The workpiece's material was AISI P20 tool steel, cut into a semi-circular shape (100 mm in diameter and 10 mm thick) [5]. Graphite, copper and brass each have a semi-cylindrical diameter of 12 mm. When surface integrity was considered, the testing findings showed that brass was the best electrode material for the AISI P20 tool steel, whereas graphite was the worst.[6]

EDM machinability of SiCw/AI composites was published in the material science journal by M. Ramulu and M. Taya. The experiment uses metal matrix composites with a volume percentage of 15 and25 percent. These plates were made of SiC whisker/2124 aluminum matrix (SiCw/AI) composites, which had a thickness of 6.3mm and were in a plate shape. A copper and brass electrode with geometrical symmetry [7] was employed as an electrode material. Copper electrodes have a lower material loss rate than brass electrodes at 25% vol. SiCw/A1 SiC. Compared to a 15 percent SiCw/al composite, machining times are 25% longer when using SiCw/A1. High-speed EDM has been shown to cause significant surface microdamage.

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A study by Munmun Bhaumik and Kalipada Maity examines the effect of electrode materials on several EDM characteristics of titanium alloys. A comparison of the alloy's EDM performance was carried out in this paper. Copper, brass, and zinc electrodes are used in titanium Ti5Al2.5Sn. Surface roughness (Ra), surface crack density (SCD), radial cut (ROC), and reflow layer are all critical performance metrics to keep in mind. Pulse duration, offset voltage, and duty cycle is also examined with these parameters. A microstructural investigation is carried out on the machined surfaces of several electrode materials. Copper electrodes were found to have the best surface finish, and the least radial overcut, followed by brass and zinc. [8]

For the Institute for Werkzeugmaschinen and Fabrikbetrieb (IWF), Eckart Uhlmann and Markus Röhner produced an article on using novel electrode materials in micro-EDM to reduce tool electrode wear. B-CVD diamond and polycrystalline diamond were used in experiments to reduce the wear on tools (PCD). Because of their melting points and thermal conductivity, these materials are ideal for electrode materials... Even though PCD has a lower specific electric resistance than B-CVD, more research is needed to determine whether PCD can be used in industrial applications. Studies into the effects of grain size and cobalt concentration on material removal and wear mechanisms are needed before PCD can be recommended for industrial use. [9]

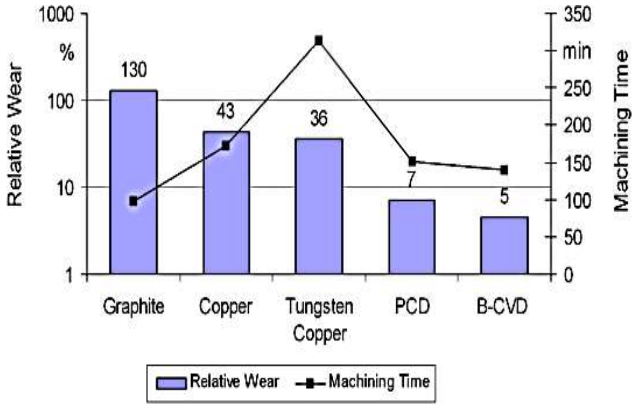

Figure 2: -Influence of electrode material on relative wear and machining time [10].

M.P. Jahan, Y.S. Wong and M. Rahman have studied the fine-finish die-sinking micro-EDM of tungsten carbide using different electrode materials. They found that tungsten, (W), copper tungsten (CuW), and silver tungsten electrodes were all effective at producing fine surface finishes in micro EDM of Wc. The article's authors concluded that the machining voltage and discharge current are responsible for surface properties. However, the CuW electrodes removed the most material, followed by the AgW electrode, which generated a smoother and defect-free Nano surface with the lowest Ra and Rmax of the three electrodes. The least worn electrodes were W, CuW, and AgW. When all the process factors were considered, AgW was the best option.

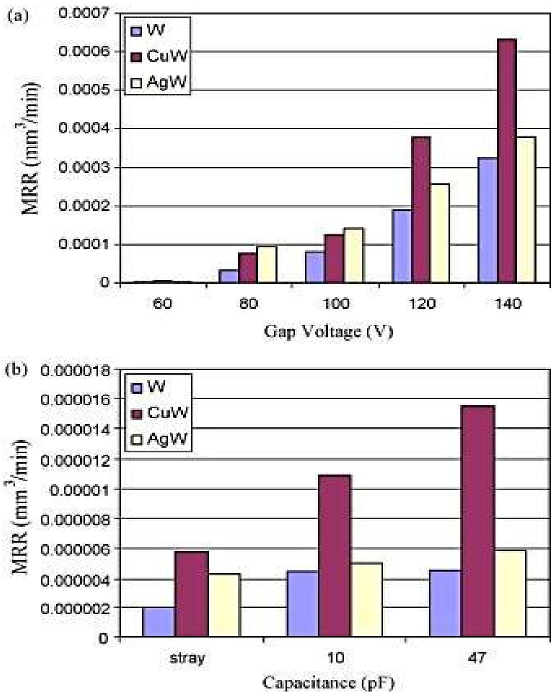

Figure3: - Variation of MRR concerning (a) gap voltage (at stray capacitance) and (b) capacitance (at 60 V) for the fine-finish micro-EDM of WC using different electrode materials. Article by Smrutirekha Pani and Manoj Masanta, "Experimental examination of AA6063 aluminium alloy machining with EDM utilizing hexagonal tool electrodes," describes their work on this subject. Variations in the current supply, pulse on/off durations, and gap voltage were used in this experiment. The peak current, pulse-on duration, gap voltage, and duty cycle significantly impacted machining performance [12].

Electric Discharge Machining: A Review of the Latest Developments There are three people involved in this study: Sachin S Chaudhari, A M Nikalje, and G E Chaudhary. With a brief literature review, precision wire EDM is examined in detail in this work. Steels and tool metal alloys, for example, were the primary focus [13].

Nalin Somani, Yogesh Kumar Tyagi, and Parveen Kumar have reviewed different copper based EDM electrodes fabrication methods. Alternatives to the typical procedures used to create electrodes for electro-discharge machine tool electrodes are provided. The physical qualities of the electrodes are critical since EDM is typically used to make high- precision dies. Powder metallurgy, rather than rapid prototyping or electroplating, has been determined to be the best process for electrode fabrication [14].

A team led by S. Ganapathy, M. Palanivendhan, P. Balasubramanian, M. This study aims to optimize machining parameters to reduce the number of tools required for EN8 steel EDM using Suresh's response surface methodology (RSM). Increases the rate of wear and the pace of withdrawal of inventory. Peak current (I), pulse-on time, pulse-off time, and dielectric pressure were all considered during the process. Analytical variance (ANOVA) optimized machining settings by conducting RSM trials. With the maximum MRR and minimum TWR of 71.366 mm3/min and 10.982 mm3/min, EN8 steel can be optimally machined, according to this

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procedure. [15] Copper tungsten electrodes have the highest material removal rate compared to other materials examined.Research into the performance of copper electrodes while machining nickel-based super alloys is covered in the paper Electrical discharge machining (EDM) of Inconel 718 by employing copper electrodes at increased peak current and pulse length by S Ahmada and M Lajisb. In order to achieve a high rate of material removal, it was determined that the current needed to be between 20A and 40A and the pulse duration between 200s and 400s. We found that the lowest surface roughness was reached at 20A and 200 ns pulse duration. For high Material removal rates, peak current is the most critical factor, while pulse duration does not significantly impact the MRR. It is possible to increase the wear rate by increasing the pulse duration. When high peak currents are employed, it hurts the rate of wear. Using the lowest possible current and voltage settings can help reduce surface roughness [17]. Using a support vector machine and a grey relational analysis, Somvir Singh Nain, Dixit Garg, and Sanjeev Kumar evaluate and analyze cutting speed, wire wear ratio, and dimensional deviation of superalloy Udimet-L605 WEDMs. After parameter optimization, the WWR and DD values were higher at high thermal energy generation than at low thermal energy generation [18]. The investigation of three-electrode materials was seen in the publication Performance Evaluation of Electrode Materials in Electric Discharge Deep Hole Drilling of Inconel 718 Superalloy by P Kuppan, S Narayanan, R Oyyaravelu, A S S Balan. However, copper electrodes have a higher wear rate than copper-tungsten and graphite electrodes [19], even though copper-tungsten electrodes and graphite electrodes are both inferior material removal and surface finish.

It is covered in Kapil Kumar & Sanjay Agarwal's paper, multi-objective parametric optimization on wire electric discharge machining. The parameters of the wire electric discharge machine are optimized and an attempt is made to discover the best possible parameters to use. Using Taguchi's method, it was possible to determine the best parameter design for material removal rate and surface finish by experimenting with a wide range of parameters, including pulse peak current, pulse-on time, pulse-off time, wire feed, wire tension, and flushing pressure. Various mathematical models and answers, such as non-regression analysis, were examined because each performance's combination of elements is unique. Furthermore, multi-objective optimization techniques were used to improve each of these models. Optimized parameters were shown to increase the efficiency of a WEDM [20]. In the publication, "Experimental Investigation on the Influence of Process Parameters for Machining AISI 310 on EDM," the authors investigated the effect of process parameters on EDM performance. Material removal rate, surface roughness, and tool wear rates for different electrode materials like copper, bronze, and aluminum were studied experimentally by A. Chandrakanth, K. Gurubrahmam, Dr. Aleem Pasha, and TN Aditya. According to the experiment, there is a clear correlation between the rate of material removal and the amount of current flowing through the machine. Even under the same settings, copper electrodes exhibited a better MRR than aluminum and bronze. A suitable material removal rate and good surface polish can be achieved using EDM when working with an alloy like AISI 310. When copper electrode material is superior to aluminum and bronze, the Taguchi method or grey relational analysis can be utilized to optimize the process. [21]

Titanium Alloy EDM Aspects in Different Electrode Materials, by Munmun Bhaumikand EDMed Ti-5Al- 2.5Sn titanium alloy electrodes, have been studied in detail in Kalipada Maity, a work published by the Indian Institute of Science. Different types of electrode materials used to machine Ti-5Al-2.5Sn titanium alloy were compared in this work. Surface roughness (Ra), surface crack density (SCD), radial overcut (ROC) and recast layer were some of the process metrics utilized to evaluate electrode performance. Variations in spark gap voltage, current, and time were used to observe the results. Brass and zinc electrodes have the best surface finish, whereas copper electrodes have the least radial overcuts. On the other hand, Copper tools are advised for greater precision and a better degree of polish. To achieve textures that are all the same, As the EDM process settings were tuned, low-speed cutting forces were reduced by the textured geometry of the tools compared to conventional devices. Even if the material is difficult to process using standard methods, electric discharge texturing is easy to produce textured tools. Establishing

Optimum Process Parameters for Machining Titanium Alloys (Ti6Al4V) by K. M. Sivakumar and R. Gandhinathan investigated the use of spark discharge machining to test various electrode materials on titanium alloys. The experiment made use of avariety of electrode materials, including electrolytic copper, beryllium copper, tungsten copper, graphite, aluminum, steel (EN24), and graphite impregnated with copper. Experiments were first designed using the Taguchi method to discover the best possible settings for the spark on and off time, current and voltage to see how these factors affected the rate of material removal, tool wear, and over-cut. For titanium alloy machining, copper impregnated graphite proved to be the best electrode material. [22] A K Khanra, L C Pathak, and M Godkhindi investigated using a composite material as an electrode material for the machining process on the die-sink electro-discharge machine. Copper and graphite are the most common electrode materials, but they have poor wear resistance, which is not an optimal electrode material characteristic. They were the authors of the study. ZrB2–Cu a composite is attempted to be created as an electrode material for EDM in this experiment. It was tested using EDM electrodes made of the composite on mild steel and on the workpiece itself. This ZrB2-40% Cu composite outperformed all others in material removal rate. Compared to copper tools, the composite device had a higher MRR and lower TWR, although it had more surface roughness and overcut than copper. Finally, an ultrafine ZrB2-Cu composite was created to test against standard copper electrodes, and this composite showed a high MRR with low TWR and decreased surface roughness.

An investigation of the impact of different EDM tool materials on their performance Paper Electro discharge machine on copper plates with copper and stainless- steel wires, Lijo Paul, Ivin Jose. When copper wires are compared to stainless steel wires, the results show that the stainless-steel wires had better rates of material removal and tool wear. For a micro-hole machining process, stainless steel was a better electrode material than copper, even though the material removal rate was practically identical in both cases, and the tool wear rate was lower with the stainless-steel wire than with copper. Increasing the voltage resulted in a higher rate of material removal, but too much high voltage has a detrimental effect on the workpiece's surface roughness and mechanical qualities. The removal of machined material does not occur appropriately if the current of time is too high, hence it is not recommended. The stainless-steel electrode's maximum metal removal rate was achieved at 55 volts, 70 percent pulse on time, and 30 percent pulse off time [23]. The article concluded that the material loss rate and tool wear in copper and graphite electrodes is different while machining XW42 tool steel. Copper electrodes have a faster material removal rate and a lower tool wear rate than graphite electrodes. The tool wear rate was reduced, but the material removal rate decreased when the electrode diameter was increased along with the current. Copper electrodes remove more material from the workpiece than graphite electrodes. Still, copper electrodes are better suited for rough finishing operations, while graphite electrodes are better suited for smooth finishing operations. The best machining results come from combining the two electrode types. When the workpiece material was machined, it was discovered that graphite had a higher tool wear rate than copper [24].

In this paper, the functioning of high-speed steel has been studied using electrical discharge machining. The response parameters selected are the material removal rate (MRR) and the surface roughness (SR). All of them have been studied in terms of current intensity supplied by the generator (I), voltage (V) and pulse time (Ton). Design of experiment (DOE) techniques have been used in order to optimize and predict the most influential factors by using a small number of experiments.[25] This paper study the effect of process parameters and different type of electrodes on dimensional accuracy and surface integrity of EDMed Ti-5Al-2.5Sn titanium alloy. A comparative study has been conducted on the EDM performance of Ti-5Al-2.5Sn titanium alloy using different type of electrodes viz. copper, brass and zinc. The process performance has been measured by means of surface roughness, surface crack density, radial overcut and recast layer.[26]

Another article describes the cooling effect on copper electrode while EDM M2 grade high speed steel workpiece. For evaluating machinability, electrode wear ratio (EWR) and surface roughness (SR) were the two responses observed. Discharge current, pulse on time, duty cycle, and gap voltage were the controllable process parameters. It was found that EWR reduced up to 20% by cryogenic cooling of electrode. With electrode cooling, SR was also found to have been reduced after machining. The effect of process parameters on EWR and SR were also analyzed. It was found that for EWR, discharge current, pulse on time, and duty cycle has the most significant effect, while pulse on time and discharge current have the most significant effect on SR. EWR and SR were found to be lower in cryogenic assisted EDM as compared to conventional EDM for the same set of process parameters.[27] This article discusses the summary of the work performed by earlier researchers through a detailed literature survey. Similar literature on EDM and impact of process parameters on performance measures such as surface quality, tool wear rate and material removal rate are reviewed in this article. The challenge and limitation of EDM process faced during the maching are also highlighted in this paper.[28] Machining of Titanium Grade2 and a full-scale experimental procedure was conducted, with control parameters the pulse-on current and pulse-on time, using graphite electrode. Te MRR, TWR and AWLT were calculated as the major machining performance indexes. Moreover, a heat transfer numerical model with coupled deformed geometry was developed, in order to accurately and realistically simulate the spark erosion mechanism and to estimate parameters that cannot be obtained through experiments. Namely, the power distribution between electrode and workpiece was estimated, as well as the plasma fushing efciency.[29]

This present investigation details the determination of optimum process parameter to attain the better machining performance in EDM of Haste alloy C276. The experimental combinations are planned and analyzed by Taguchi's design of experiments approach. The influence of process variables such as current, pulse on and pulse off time were investigated to control the various desired performance measures such as Material removal rate, surface roughness and overcut. Analysis of variance (ANOVA) a statistical analysis tool has been applied to ascertain the significance of the input process variables on electrical discharge machining of Haste alloy C276. The statistical results confirmed that the current is the most influencing process variable on material removal rate, surface roughness and overcut.

Research gap

Electro discharge machining can prove to be extremely efficient if the parameters are correctly optimized, one of the factors being the electrode material. Even though selection of electrode material majorly is based on the workpiece to be manufactured, even after extensive research by various authors, one electrode material is not an ideal match for a specific workpiece material, each material has some advantages with a few drawbacks. A lot of research is still to be done for machining of composites and

parameter optimization in terms of electrode material.

4. Conclusion

This review paper on effect of various electrode material used in electro discharge machining, different electrode materials such as copper, brass, and graphite produce varied results when cutting different materials with varying machining parameters. Optimization of electrode material properties is required to achieve the desired outcome. It has also been noted that for better parameters like surface finish, low diameteral overcut, high MRR and less electrode wear a selection of a better and effective electrode material is a must. Electrode Tool materials like copper, graphite, aluminum perform better to obtain results mentioned above.

Acknowledgment

The assistance provided by Prof. M.S. Tufail and was greatly appreciated and helped us to do extensive review on electrode material used in the die sink electrode discharge machine. During the process of review completion, we gained a lot of knowledge which would help us to complete our project as well as get introduce to different concepts.

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