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Effect of Graphite as Electrode in EDM Machining Compare with other EDM Electrodes A Review

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ABSTRACT

Electro discharge machining is an important unconventional machining process being widely used in modern industrial applications and precession works. Electrode is the most vital element of the electrical discharge machining (EDM) system, working like a cutting tool, highly responsible for the qualitative and quantitative responses.However, the high temperature also impacts various physical and chemical properties of tool and workpiece. Process parameters and machining characteristics of EDM are identified in this paper. Based on the previous investigations, an analytical dependence was established between the parameters of discharge energy and technological performance. In addition, properties of discharge energy were experimentally investigated and their influence on productivity, accuracy and quality of EDM was established. Mathematical and experimental researches conducted in this paper allow development of intelligent modeling approaches for efficient selection of relevant parameters of EDM discharge energy. The results obtained represent a technological knowledge base for the selection of optimal conditions of EDM process.

Key words: EDM, machining parameters, technological performance, modeling, optimization

1. INTRODUCTION

Electrical discharge machining (EDM) is a preferred machining operation to produce intrinsic and complex geometry parts -made of difficult-to-machine materials. In electrical discharge machining (EDM), heat energy created by sparking between the work piece and the tool electrode is used to remove material from the work piece. A pulse power generator is responsible for creating the pulses required for the EDM process. Some examples of pulse power generators are the rotary impulse generator, the hybrid generator, the electronic pulse generator, the resonant generator, and the resonant generator. Pulse shape, frequency, on-time, off-time, etc. are all aspects of electrical pulses that contribute to their effectiveness in machining. Sparking is triggered by the potential difference between the tool and the work item, which is created by the pulses. Sparking causes a very high temperature between the electrodes, which removes material and causes tool wear by locally melting and vaporising microscopic particles from the work piece and the tool electrode surfaces.

In EDM, tooling is the most important subject because it influences the overall machining time and production cost of the final product. Since both traditional and unconventional machining techniques are used to create EDM tool electrodes, the tooling process for EDM is time-consuming and costly. The term "rapid prototyping" (RP) refers to the practise of creating a working model of a product in a short amount of time. The rapid prototyping approach streamlines the creation of complex-shaped prototypes in a very short amount of time. Parts are produced by the RP technique of selective laser sintering (SLS), which involves sintering metal powders with a laser. SLS is a method of additive manufacturing in which powders are sintering layer by layer under a laser beam. Selecting a powder material for SLS processing that has appropriate qualities for use as an EDM tool electrode is important. In this study, we employ a recently designed RP tool electrode (AlSiMg) that was manufactured using the SLS technique. Rapid prototyping is used to create a novel tool electrode, which is then compared to traditional copper and brass electrodes to determine how well it performs. When employing the traditional method of tool creation, the time required to develop a tool for EDM machining of a complex item is substantial. Using the RP approach may significantly decrease the quantity of time needed to create a new tool.

2.0 LITERATURE REVIEW

Rahul, Partik Vashist et al [1]The Wear Intensity (TWR) for Tool Wear was found to be the least in copper when the method parameter values for the current discharge were set at 7A, 300µs, and 1µs, respectively, pulse on time (Ton) and pulse off time (Tuff). For Mild Steel unit, TWR was found to be the least favorable when TWR was 0.0110gm / min in response to process parameter values such as current (Ip), time pulse (Ton) and pulse out time (Tuff) were set as 21A, 300µs and 3µs, respectively, for process parameters discharge current (Ip). **Ajeet Bergaley et al [2]** Material removal rate Material removal rate is mainly affected by current followed by pulse on time and concentration of copper powder in dielectric fluid. MRR is least affected by pulse off time. Peak current is majorly contributes for MRR. MRR increases with increasing current across the spark gap. MRR increases with increasing copper concentration in dielectric concentration. **Alwin Varghese1 et al [3]** A three dimensional micro EDM model is considered both for single and multiple discharges in a RC circuit based micro EDM. The temperature distribution within the work piece is calculated by solving the model equation which was discredited using finite volume method. The present numerical results for single spark are validated with experimental data. It can be seen that the simulation. **Amit Bhatia [4]**. In the present work, the Joule heating factor was used to model the EDM process and predict the maximum temperature reached in the discharge channel. From the temperature distribution the volume of material removed from the work piece and Remix was estimated. Experiments were conducted with different pulse on-time (Ton) and current values and the material removal rate was calculated. **Aniza Aliasa [5]** In this paper, an effort was made to determine the important machining parameters for the performance of WEDM viz. kerfs width, MRR and SR. The main goal is to find the best combination of machining parameters as known the cost and quality of WEDM which depends heavily on the process parameters. **Anshuman Kumara [6]** the values between experimental and numerical model analysis result are closer which is comes 87%. Because there were some assumptions in the model when compared to the experimental value; like 100%Flushing, no ignition delays, no deposition of recast layer, etc. But in experimentally, is not possible like that, the melted material is not fully flushed out from the work piece; some amount of melted material re-solidifies in the work piece and forms the recast layer. **Avinash Deshmukh [7]** A predictive model based on heat transfer principles was developed for estimating the crater geometry during single spark machining for micro-EDM process. This model is solved by finite element method. This model used a Gaussian distribution of heat source, constant plasma radius and is equal to measured crater size, temperature dependant material properties to perform transient thermal analysis in order to predict crater geometry, temperature distribution on the work piece at different energy level. **Baljinder Singh,et al [8]** Following are the conclusions which can be taken out by varying each input parameters during machining of H11 specimen with aluminum electrode. Negative polarity of tool electrode is desirable lowering of surface roughness.

Suspension of powder particles in dielectric fluidic improves surface roughness. Higher peak currents produce more rough surfaces in EDM process.**C. K. Biswas [9]** This paper has presented the use of fuzzy logic for optimization of the EDM process with multiple performance characteristics. The following factor settings have been identified as to yield the best combination of process variables: Factor Ip= 2A, Ton= 500 μs, Tup= 1.4s, Tw= 1s and IEG= 90 μm. The performance characteristics such as MRR and SR can be improved through this approach. **C. Mascaraque et al [10]**. In this work a new numerical model for predicting the surface finish in parts produced by penetration electro discharge machining (EDM) is presented. This model consists of a simplified numerical approach with a reduced computational time to analyze the material removal and surface profile in the front side of the electrode. This mathematical model is based on the estimation of thermal energy provided by each successive spark, and is oriented to 2D numerical simulation of EDM process in a representative section of work piece material. **C.H. Che Haron, [11]**The EDM performance of copper and graphite tool electrodes was examined with XW42 tool steel. The material removal rate of XW42 tool steel with copper electrode is greater than that with graphite electrode. Copper electrode is suitable for roughing process, whilst graphite electrode is suitable for finishing process. **Cheng-Hung Chen [12]** In this study a BPNN was used to predict the surface roughness in CNC end milling. Furthermore, this study analyzed the influence of CNC parameters including cutting depth; spindle speed, feed rate, and milling pitch on surface roughness. The contributions of this study are summarized from the experimental results as follows. In the measurement experiment of surface roughness, the CNC parameters with a smaller cutting depth, a faster spindle speed, and a smaller feed rate will obtain a better surface roughness. **Deepak Kumar Prasad, et al [13]**This in the present work, the deposition of material through EDM process for multi-spark discharge is modeled and analyzed the height and the weight of the deposited copper material through COMSOL Metaphysics software. A thermal model has been developed in order to see the volume of melted material removed from the tool. **Deepak Kumar, [14]** The proposed mathematical modeling approach predicted the inter electrode gap and MRR for a single discharge pulse. Below points showing the major conclusion from the above studied. The validation against the experimental results showing the correctness of the predicted model the error in predicted model was found less than 5 % and 35% for inter electrode as well as for MRR. **Drossel, W.G. a,b; Bucht et al [15]** Using various adaptronic systems can provide higher performance of cutting processes. The use of fast tool servos (FTS) systems for adaptronic form honing and adaptive spindle control during the investigations showed shape accuracy, surface roughness and productivity. **E. Weingärtnera [16]**. A thermo-electrical model was used for predicting the MRR of different materials. In comparison to point and disc heat sources, a time-dependent heat source was found to be more suitable to predict the shape of eroded craters. Moreover, better simulation results were achieved when considering the material properties as temperature-dependent. **Farook Nehad Abed [17]** In This Study, The Mrr, Ewr and Overcut In EDM Process Of Titanium Alloy Using U-Shaped Cu Electrode Were Modeled And Analyzed Through Rsm. Pulse On Time, Pulse Off Time, Peak Current, Spark Gap Voltage Have Been Employed To Carry Out The Experimental Study. **G Krishna Mohana Rao, [18]** From the experiments that were conducted on the Die sinking EDM and the ANN models developed, the following interesting conclusions are drawn: When current increases at constant voltage, MRR increases. Maximum MRR takes place at a voltage of 40V and 16A. **Hardik N. Mehta et al [19]** The reported theoretical models based on thermal analysis have limited applicability, as they are based on the assumptions like the use of constant spark radius, approximation of heat source to a point or disc shaped (uniform) and constant thermal properties of work/tool materials. **Jayaraj Jeevamalar [20]** In the current work, the ANN model has been developed for the EDM drilling process for machining of Ancones 718 with the hollow tubular copper electrode. The training and testing of ANN for input-output patterns are administered by through Neural Network Toolbox in Mat lab 2009 software package.

3.0 METHODOLOGY

EDM is a process of removing electrically conductive materials by means of rapid and repetitive spark discharges that occur between the tool electrode and the

workpiece at the presence of dielectric oil. During the EDM process, a conductive tool electrode with the desired geometry is brought to close proximity of the workpiece by maintaining a small gap known as a spark gap. Both the workpiece and electrode, especially the spark gap zone of the electrode and the workpiece, are submerged in the dielectric fluid. The electrical voltage is applied between the electrode and the workpiece, which results in a series of sparks causing the breakdown of the dielectric, which in turns results in an intense amount of heat, eventually melting and evaporating the materials from both the workpiece and the electrode The dielectric flushing is used to remove the machined craters from the spark gap, and to draw fresh dielectric into the spark gap for the next series of sparks to take place. The basic mechanism of material removal in EDM is similar to the micro-EDM process, but with significant differences in the process mechanism, capabilities, and machine tools used for the processes.

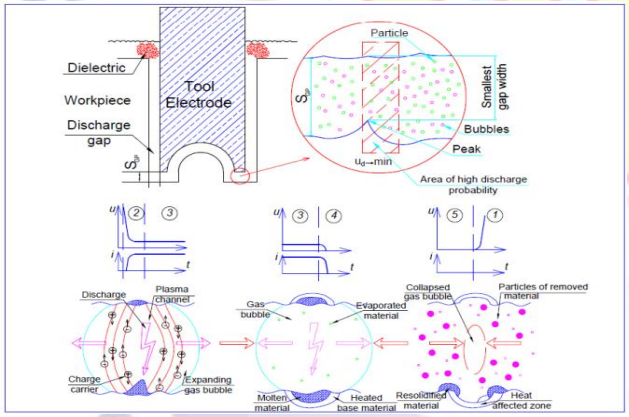

Figure:Machining principles of EDM

Experimental Procedure:

- The electric discharge machine, model TOOLCRAFT G-75(die sinking type) with servo-head and positive polarity for electrode (reverse polarity) will be used to conduct the experiment. Industrial grade EDM oil is used as a dielectric fluid. These are the steps in the procedure of the experiment.
- The copper electrode is taken whose diameter and length are then checked to ensure that the dimensions are according to the specification.
- The mass of the electrode in its initial stage is measured using a pocket weighing scale. The workpiece mass values are consequently taken with the balance having higher weighing capacity.
- The work material (AISI 1040) was mounted on the v-block and positioned at the desired place and then clamped. The electrode was clamped on the adjustable slot whose alignment was checked by Try square.
- The parameters like Pulse-on-time and discharge current were set-up initially and later changed for every reading to obtain the varying depths of cut thereby making us enable to calculate the M.R.R and T.W.R for various values.
- After machining operation, the electrode and the workpiece are taken out and weighed again on the balances.so that the mass values are obtained for calculations.
- The same experiment was repeated with 2 types of electrodes with 9 holes being made on a single workpiece by each electrode. The data is taken and calculations are performed.

Graphite:

It is most widely used electrode material and is best non-metal material used as electrode. It is cheap and is easily available and is highly stable. It is very brittle thus cannot be used for making small electrodes. It is therefore used for making large cavities. Graphite however has a property of arcing so to prevent that anti arcing devices are incorporated in set up.

Table: Graphite Material properties

Properties	Value
Thermal Conductivity (W/m°C)	53.66
Density (g/cm^3)	7.85
Melting point (°C)	1,495
Young's Modulus (GPa)	400

Table:1 Review on EDM Machining Compare with Other EDM Electrodes

Reference	Study	Discussions
Prabhakar Reddy. P [21]	To study the influence of copper electroplating on Aluminum electrode by varying parameters such as Pulse on time (50µs,70µs and	To Investigation it has been found that the tool wear rate of copper coated electrode is less than Pure Aluminum electrode, which

	80μs) and discharge current (10 A,15A,20A).	implies that the copper coating prevents the tool from wearing out
Apiwat Muttamara [22]	This paper presents a study of surface's characteristics by EDM in de-ionized water due to decarbonization.	In addition, the hardness of the recast layer machined with graphite electrode was higher than that of the recast layer machined with copper electrode.
Yuchao Jia [23]	This study aims to control the final geometric accuracy of deep and narrow slot machining by optimizing electrical parameters.	Variations in size and material may change the specific optimal parameter selection accordingly. Therefore, it is necessary to perform similar work for another different situation to improve the processing results.
Nayan J. Patel [24]	Electrode is considered as tool in EDM process. Selection of the electrode material plays vital role in the EDM process. Different electrode materials have different properties.	Cost of manufacturing electrode is about 50% of total cost of EDM process. Powder metallurgy processed electrode shows better performance than electrode manufactured by conventional methods.
Rahul Mahajan [25]	In the present paper a detail study has been done over different copper and copper-based electrodes used in EDM process.	Thus, Brass electrode has the highest TWR followed by copper electrode and then copper tungsten electrode. MRR increases with the increase in peak current for all electrode material
Tiago Czelusniak [26]	This article reports a literature review on the diversity of conventional and non-conventional materials that are used or have potential to be used as EDM electrodes	In this context, metal matrix composite materials are a potential alternative to unify the desired properties of different materials in an EDM electrode directly processed by SLS/SLM.

3.1 Discussions

Electrical discharge machining (EDM) is a very common type of machining in manufacturing industries. Thereby, the machining characteristics of EDM mainly depend on generation and distribution of discharge energy within the machining zone. The energy generated depends on the discharge current and discharge duration, while the distribution of energy depends on physical and chemical characteristics of the discharge zone.EDM is slow machining process and the tool wear is high. The modern industries are facing challenges from advanced materials such as super alloys, composites, and ceramics that are hard and difficult to machine, with high precision, a surface quality associated with higher machining cost. Most of the research focused on solid electrode usage which are higher in costing even for finishing work pieces also. For low material removal rates and high quality surface finish researches are still need to control production costs by decreasing machining costs.

Due to low wear it is time and cost effective.

Easier machining with less complex milling tools Perfect for high quality surface finishes and provides a high metal removal rate.

It does not melt but sublimes (turns from a solid to a gas) at very high temperatures of 3400 ºC.

It is five time less dense than Copper which means lighter electrodes.

It is very resistant to thermal shock and can withstand high temperatures.

As graphite has become more affordable, EDM machining shops will often use two or even three main grades of graphite.

These include:

- Large grain graphite (about 20 μm) with low densities (1.76 g/cm3) Fine grain graphite (~10 μm) of high density (1.82 g/cm3)Very fine grain graphite (~4 μm) with densities greater than 1.86 g/dm3.
- With very fine graphites the surface finish improves and the wear decreases. The only downside to finer graphites material removal is less and prices increase.
- The higher the flexural strength, the lower the wear and the easier it is to machine in fine detail.

4.0 CONCLUSION:

The effect of discharge current and pulse duration has been taken into consideration in various research works but variation in pulse interval has not been investigated.Most of the available research works on powder mixed dielectric have studied the impact of such machining on MRR, surface roughness and TWR etc. with normal polarity.However most of the experimental research has a simplistic approach and tries the variation of dielectric (hydrocarbons and water based) and electrode materials (Copper, tungsten, graphite etc), leads to higher machining costs even finishing jobs. By using solid electrodes, manufacturers can achieve faster machining speeds while still maintaining high quality surface finish, which is beneficial for high-volume production. However, due to the high cost of the electrodes, research is still needed to find ways to reduce production costs while still achieving the desired results. This method of using graphite coated ceramic electrodes not only improves the surface finish of the machined part, but also reduces the cost since the electrodes last longer and require less frequent replacement. Additionally, the use of graphite coated ceramic electrodes improves the machining speed, allowing manufacturers to achieve higher production volume in shorter time. Coating of graphite on ceramic metals used as an electrode can decrease finishing costs. Researches on this area focusing the future reserch as a scope.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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