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Performance Evaluation of Copper Coated Aluminum Electrodes in EDM Process

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ABSTARCT: The electrical discharge machining process is one of the non-traditional processes used in the field of manufacturing. In this process a formed electrode tool produces the shape of the finished work surface. Electrode materials are high temperature, but easy to machine, thus allowing easy manufacture of complex shapes. Typical electrode materials include copper, tungsten, and graphite. The main focus of our thesis is to study the influence of copper electroplating on Aluminum electrode by varying parameters such as Pulse on time(50µs,70µs and 80µs) and discharge current(10 A,15A,20A).The resultant Metal Removal rate obtained on the AISI 1040 workpiece and Tool wear rate of the electrodes were studied and comparisons were drawn between Regular Aluminum electrode and copper coated Aluminum electrode. The aim of the experiment was to achieve the Minimum tool wear rate for the copper coated Aluminum electrode and maximum Metal removal rate of the AISI 1040 workpiece using the same copper coated Aluminum electrode.

KEYWORDS: Electrodeposition, Copper coated, Pulse ON time, Pulse OFF time, Current.

ABBREVIATIONS: EDM, Electrical discharge Machining; MRR, Metal removal rate; TWR, Tool wear rate; SR, Surface roughness.

1.INTRODUCTION

The Electrical discharge Machining process is a thermoelectric process which removes the material from the workpiece in the form of discrete sparks. This eliminates the chances of mechanical stress, chatter and vibration problems, as is prominent in traditional machining. Therefore, this process is categorized under Non-traditional machining process. [2]A formed electrode tool produces the shape of the finished surface. Common methods of evaluating machining performance in EDM operation are based on the following performance characteristics: MRR, SR, and EWR. Basically, these characteristics are correlated with the machining parameters such as work piece polarity, pulse on time, duty factor, open discharge voltage, discharges current and dielectric fluid. Proper selection of the machining parameters can obtain higher material removal rate, better surface roughness, and lower electrode wear ratio. Machining takes place by the discharge pulse from the cathode to the anode. Usually, the polarity is set, so that the work piece acts as the anode and the tool electrode acts as the cathode, in order to obtain a higher material removal rate. The discharge pulse gap is relatively small, thus the accuracy of components or parts manufactured by EDM is very high. EDM is accomplished with a system comprising two major components: a machine tool and power supply. The sparks are generated by a pulse generator, between the tool electrode and the work material, submerged in a liquid dielectric such as Kerosene, leading to metal removal from the work material by erosion and vaporization. The EDM phenomenon, as it is understood, can be divided into three stages namely application of adequate electrical energy, dielectric breakdown, sparking and expulsions (erosion) of work material. The spark erosion of the work material makes use of electrical energy, converting them into thermal energy the rough a series of repetitive electrical discharges between the tool electrode and the work material electrode. The thermal energy generates a channel of plasma between the two electrodes and the breakdown of plasma channel occurs, resulting in a sudden reduction in the temperature, allowing the circulating dielectric fluid to flush away the molten work material from the EDM machined surface in form of microscopic debris. Melting and vaporization of the work material dominates the material removal process in EDM, leaving tiny craters on the surface of the work material. Material removal rate (MRR) for EDM operation is somewhat slower than with traditional machining methods, where chips are produced mechanically. [4]The rate of material removal is dependent upon the following factors: amount of pulsed current in each discharge, frequency of the discharge, electrode material, work material and dielectric flushing condition. Diameter overcut (dimensional accuracy) becomes important when close tolerance components are required to be produced for space application and also in tools, dies and molds for press work, plastic molding and die casting. The rate at which the electrode wears is considerably less than that of the work material. In EDM, each electrical spark discharge produces a tiny spherical crater in the work material by local melting and vaporization. With high sparking frequencies the spark erosion gives substantial metal removal rates. The depth of the crater defines the surface finish which in turn depends on the current, frequency, and finish of the electrode. The metal removal rates and surface finish are controlled by the frequency and intensity of the spark. Surface finish produced on machined surface plays an important role in production. It becomes more desirable so as to produce a better surface when hardened materials are machined, requiring no subsequent polishing. Surface finish is also important in the case of tools and dies for molding as well as drawing operations. With EDM processes, work piece surface modifications can be well controlled and highly accurate geometric predictions can also be made. However, the machining characteristics of EDM remain unclear, especially in regard to the total energy of discharge pulses and tool electrode wear, since the energy is not only used to machine the work piece, but also degrades the tool electrode. Hence, the accuracy of the components machined by EDM is also influenced by the wear of the tool.

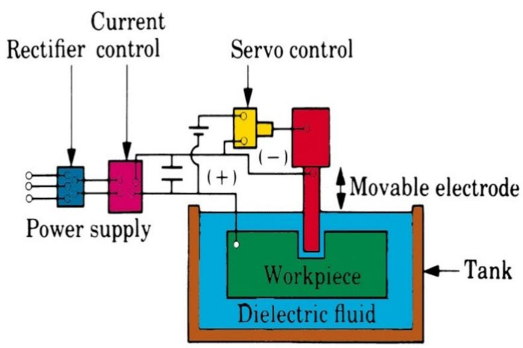

Fig 1: Setup of EDM

2..MATERIAL AND METHOD

2.1.Copper electroplating: Standard Aluminum alloy extruded rods (diameter of 16 mm) available in the market were used for preparation of copper-coated electrode. This rods then undergo electroplating process in the industry. Here, prior to anodization, [9] the Aluminum alloy specimen was degreased in 100 g/l NaOH solution for some duration around 5 min, then it is rinsed in distilled water and it is then clarified in a solution of nitric and hydrofluoric acids (3:1). Properly cleaned Aluminum alloy specimen was anodized in anodizing solution at anodic current density of 20 mA/cm2 in the room temperature. The anodizing solution was composed of sulfuric acid (150 ml L^{-1}), phosphoric (150 ml L^{-1}) and ammonium bi-fluoride (2 g L^{-1}). The copper was deposited on anodized specimen from copper sulphate electrolytic bath. The electrolytic bath was composed of copper sulphate (200 g L^{-1}) and sulfuric acid (20 ml L^{-1}). The copper was used as an anode and anodized 6061 Aluminum specimens was used as a cathode. The electrodeposition was carried out with cathodic current density of 20 mA/cm2 for 2 h.fig.1.0 shows the electrode before and after electroplating

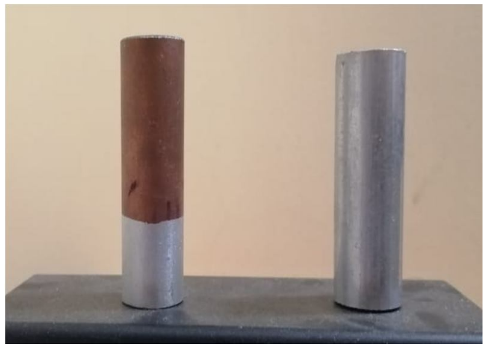

Fig.2: Aluminum electrode before and after electroplating

2.2.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.

1.The copper electrode is taken whose diameter and length are then checked to ensure that the dimensions are according to the specification.

2.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.

3.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.

4.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.

5.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.

6.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.

3.calculations

3.1.Calculation of Metal Removal Rate (M.R.R)

Higher the material removed per minute; more will be the material removal rate. The MRR is a single number that enables you to do this. It is a direct indicator of how efficiently you are cutting, and how profitable you are. MRR is the volume of material removed per minute. The higher your cutting parameters, the higher the MRR. The material removal rate in a work process can be calculated as the depth of the cut, times the width of the cut, times the feed time.

The material removal rate is typically measured in cubed per minute (mm3 /min).

M.R.R(mm3 /min) = $\frac{d*a}{t}$

d= depth of the cut (mm)

a =area of the cut (mm2)

t= time in min

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3.2.Calculation Of Tool Wear Rate

Tool wear is an important factor because it affects dimensional accuracy and the shape produced. Tool wear is related to the melting point of the materials. Tool wear is affected by the precipitation of carbon from the hydrocarbon dielectric on the electrode surface during sparking. TWR is expressed as the ratio of the difference of weight of the tool before & after machining to the machining time and density of the material. That can be explain this equation.

$$\text{TWR (mm3 /min)} = \frac{Wta - Wtb}{\rho * t}$$

Where Wtb= Weight of the tool before machining (gm)

Wta= Weight of the tool after machining (gm)

t = Machining time (minute)

ρ = Density of metal in gm/mm3

Fig 3:Placing of Electrode and Workpiece

Table 1: Data Collection and Calculation At 10 Amps Current

Electrode	Initial mass	Final mass	Depth of cut	Pulse on time	Current(A)	M.R. R	T.W. R
Aluminum	27.27	27.23	0.11	50	10	8.84	1.48
Aluminum	26.18	26.01	0.47	70	10	37.78	6.27
Aluminum	25.11	24.89	0.63	80	10	50.64	8.12
Cu-Al	26.73	26.7	0.14	50	10	11.25	1.11
Cu-Al	26.35	26.22	0.50	70	10	40.19	4.8
Cu-Al	25.61	25.43	0.69	80	10	55.46	6.64

Table 2: Data Collection and Calculation At 15 Amps Current

Electrode	Initial mass	Final mass	Depth of cut	Pulse on time	Current(A)	M.R. R	T.W. R
Aluminum	24.89	24.17	0.75	50	15	60.29	26.57
Aluminum	27.23	26.89	0.85	70	15	68.33	12.55
Aluminum	26.01	25.65	1.86	80	15	149.51	13.28
Cu-Al	25.43	24.98	0.83	50	15	66.72	16.61
Cu-Al	26.7	26.62	0.87	70	15	69.93	2.95
Cu-Al	26.22	25.97	2.01	80	15	161.57	9.23

Table 3: Data Collection and Calculation At 20 Amps Current

Electrode	Initial mass	Final mass	Depth of cut	Pulse on time	Current(A)	M.R. R	T.W.R
Aluminum	25.65	25.11	0.7	50	20	56.27	19.93
Aluminum	24.17	23.27	0.68	70	20	54.66	33.21
Aluminum	26.89	26.18	2.43	80	20	195.33	26.2
Cu-Al	25.97	25.61	0.74	50	20	59.48	13.28
Cu-Al	24.98	24.41	0.79	70	20	63.5	21.03
Cu-Al	26.62	26.35	2.81	80	20	225.88	9.96

4.0. Results and discussion:

4.1. Discussion on Metal removal rate(M.R.R).

Highest value of M.R.R is found for the Copper-coated Aluminum electrode at a pulse on time of 80µs with a value of 55.46 which is greater than that of Aluminum electrode and it is also found that lower the pulse on time the lower is the value for M.R.R.

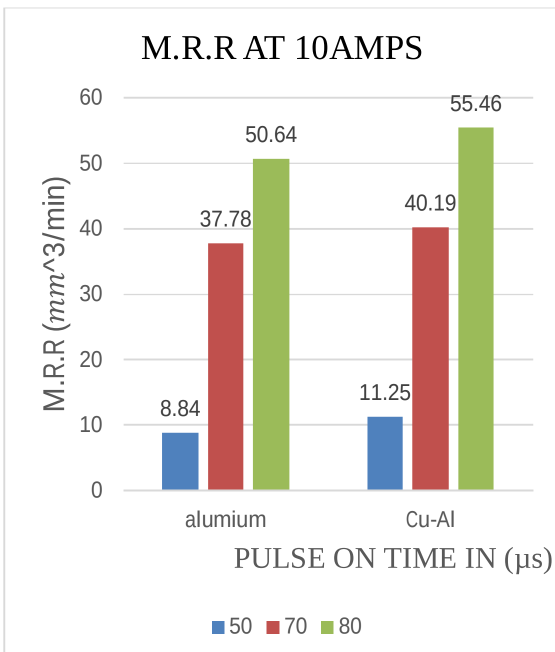

Fig 4: Comparative Graph Of Metal Removal Rate At 10 Amps

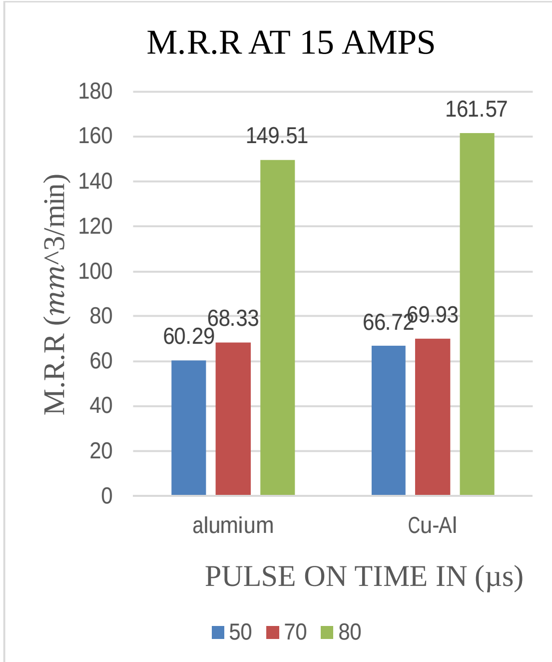

Fig 5: Comparative Graph of Metal Removal Rate At 15 Amps

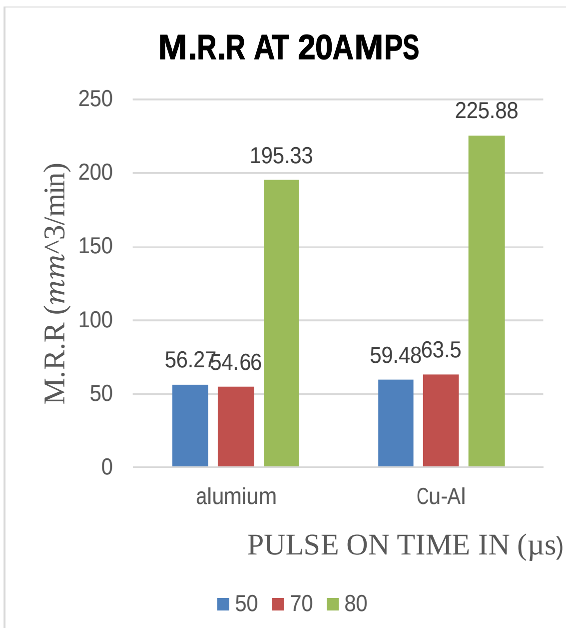

Fig 6: Comparative Graph of Metal Removal Rate At 20 Amps

4.2.Discussion on Tool wear rate (T.W.R)

It is found that with increase of pulse on time at a current of 10 A, the tool wear rate (T.W.R) varies drastically .But as the value of current increases to 15 A and consequently 20 A, at same readings of pulse on time the value of Tool wear rate decreases. The highest value of tool wear rate is found for the Aluminum electrode only in all the cases compared to the copper-coated Aluminum electrode.

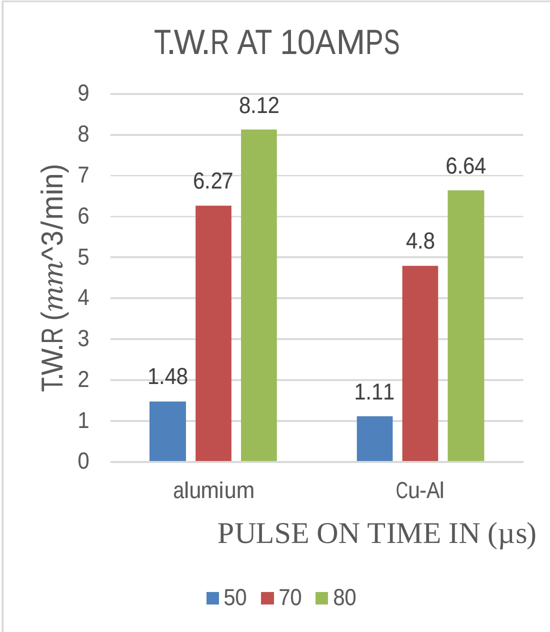

Fig 7: Comparative Graph of Tool Wear Rate At 10 Amps

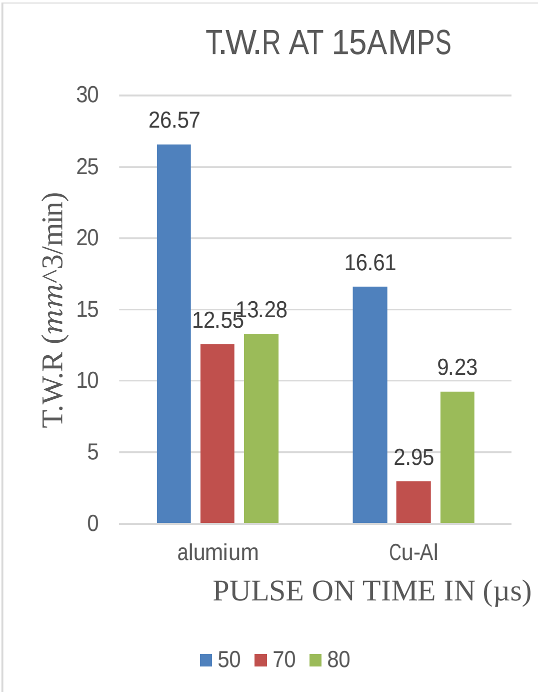

Fig 8: Comparative Graph of Tool Wear Rate At 15 Amps

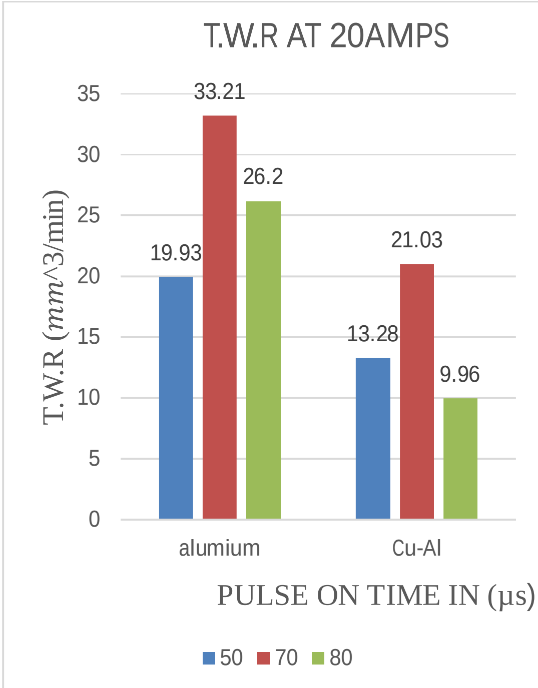

Fig 9: Comparative Graph of Tool Wear Rate At 20 Amps

5. Conclusions:

The experiment investigates the various machining characteristics using different electrode materials, thereby highlighting the enhancement of properties due to copper electroplating.

Initially the Aluminum electrode had low Metal Removal Rate, but after copper electroplating of 30 microns it has been observed that the M.R.R had showed a significant increase.

Via experimental investigation it has been found that the tool wear rate of copper coated electrode is less than Pure Aluminum electrode, which implies that the copper coating prevents the tool from wearing out.

6. Future scope

The performance of the tool can be further improved by using high grade coating materials such as graphite and tungsten carbide as well as ceramic coatings like Al2o3 in place of copper coating .The machining capabilities can be further increased by using additives nano particles in dielectric fluid which increases abrasion on workpiece,

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