An Experimental Investigation of Electrode Wear Rate Using EDM with Different Electrode Materials

ANKIT PATEL, T S BISONIYA

Abstract— **Electrical discharge machines (EDM) remove metal from a work piece by using a series of electric sparks to erode material. An electrical discharge machine is considered to be the most precision oriented manufacturing process and is widely used for creating simple and complex shapes and geometries. EDM is a machining method primarily used for hard metals or those that would be impossible to machine with traditional techniques. One critical limitation, however, is that EDM only works with materials that are electrically conductive. EDM is especially well-suited for cutting intricate contours or delicate cavities that would be difficult to produce with a grinder, an end mill or other cutting tools. Different electrode materials shows a great influence on the desired quality so here we have focused some different electrodes that we can use for surface modifications and better results so that the way ahead has been opened for further scope of work. The results reveal that low electrode wear rate (EWR) has been achieved with copper electrode (0.06 mm3/min) and brass electrode gives more electrode wear rate among other two electrodes.**

Index Terms— **Electrical Discharge machining, E.W.R, Different Electrode materials, Pulse on time, Peak current**

I. INTRODUCTION

Electro discharge machining (EDM) is a thermoelectric process that removes material from the work piece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium. The method of removal of metal from the work piece is by melting and vaporizing minute amounts of electrode material, which are then ejected and flushed away by the dielectric fluid. The basic concepts of EDM process is cratering out of metals affected by the sudden stoppage of the electron beam by solid metal surface on the anode (Fig.1). The portion of the anode facing the direct electric pulse reaches the boiling point. Even in case of medium long pulse the rate of temperature increases in tens of millions of degree per second which means dealing with explosion process. The shock wave produced spreads from the center of the explosion inside the metal and deforms crystals. In the very small duration of the process the entire energy can only be expended in the surface layer of the anode.

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Actually, the mechanism of thermal conductivity has no time to start before violent process of energy transfer is completed. When suitable pulse voltage is applied across two electrode separated by a dielectric fluid, the latter breaks down. The electrode so liberated, are accelerated in presence of electric field collide with the dielectric molecules. The resistance of dielectric layer drops as it is ionized resulting into ultimate breakdown. The electric energy is discharged into the gap and multifarious actions take place electrodynamics waves set in and travel at high speed

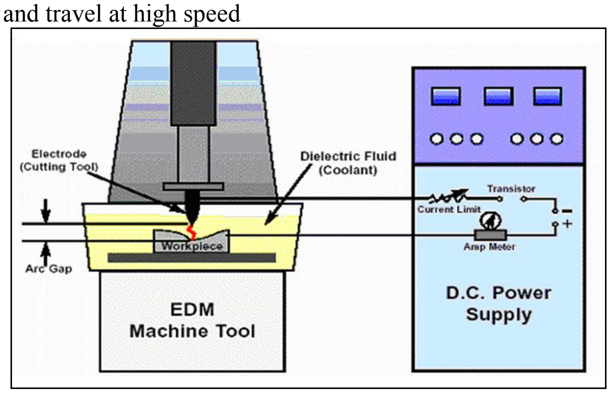

Fig.1.Basic EDM System.

P.Janmanee et.al. worked on performance of different electrodes materials in EDM of Tungsten carbide. They found that negative polarity graphite electrode has the most MRR 11% & both powder electrodes give the better MRR and EWR more than solid electrode & increased current has influence to increasing of MRR. [1].C H CHE HARON et.al experimented on the influence of machining parameters when machining tool steel using EDM with copper with different diameter electrode and used AISI 1045 tool steel as a work piece. They found that MRR and EWR were not only dependent on the diameter of electrode [2]. M M RAHMAN et al. worked on Experimental investigation into EDM of stainless steel 304.They used cylindrical copper as a electrode with positive polarity. They found that all values of pulse duration the material removal rate increases as pulse current is increased [3]. C Ogun, et.al. worked on The Effect of Machining Parameters on Tool Electrode Edge Wear and Machining Performance in Electric Discharge Machining (EDM).It is found that the WRR and TWR are increased with the increasing discharge current [4]. S H Tomadi et.al worked on Analysis of influence of EDM Parameters on Surface quality, MRR, EWR on Tungsten carbide using copper tungsten electrode & used tungsten carbide as work piece. They found that higher pulse on time will give the higher value of MRR of Tungsten carbide. Increasing of pulse off time will decrease the MRR when the voltage is increased, the MRR & EW will increase when the peak current is increased, MRR & electrode will increase when the pulse on time increased, and the EW will also increase [5]. Y.S.Wong et.al. worked on EDM performance of TIC/Copper based Sintered electrode like Copper based Sintered & Titanium Carbide (TiC) material as a work piece. They found that electrodes with 15% Tic show the highest relative density, lowest electrical resistivity, and good EDM performance [6]. A. A. KHAN worked on Electrode wear and MRR during EDM of aluminum and mild steel using copper and brass electrodes. Though a higher current causes more removal of work material and the electrode, but comparatively more material is removed from the electrode [7]. C J Luis et. al. worked on MRR and EW study on the EDM of Silicon carbide using Silicon carbide electrodes & Silicon carbide as a work piece. They found that MRR greatly increases when intensity and open-circuit voltage is increased. EW decreases when intensity is increased when flushing pressure is increase improve the wear on the electrode [8] .HARPUNEET SINGH worked on Investigating the Effect of Copper Chromium and Aluminum Electrodes on EN-31 Die Steel on EDM Using Positive Polarity. It is found that hardness is better for brass as compared with copper chromium, maximum hardness was obtained at 6A for copper chromium and 12A for brass[9]. SAMEH S. HABIB worked on Study of the parameters in electrical discharge machining through response surface methodology approach. They used copper as a electrodes (99.7% Cu, 0.12% Zn, 0.02% Pb, 0.02% Sn) with positive polarity. It is observed that surface roughness increases with the increase of pulse on time, SiC percentage, peak current and gap voltage [10]. Marafona et al. investigated the influence of the hardness of the alloy steel on material removal rate and surface roughness of the work material [11]. Jahan *et al.* worked on micro- EDM of tungsten carbide using different electrode mate-rials of tungsten, copper tungsten and silver tungsten and reported that silver tungsten electrodes are capable of producing smooth and shiny surfaces with negligible amount of surface defects [12]. Mohd Abbas et al. presented the current research trends on machining and modeling techniques in investigating EDM performances [13]. While studying the machining characteristics of tungsten carbide-cobalt composite and ceramics by EDM process, it is observed that increasing the pulse time enhances the machining instability which has significant effect on the surface finish of the workpiece [14]. Experiments which were carried out on AISI P20 tool steel as work material and copper as electrode show that the roughness of finished surface increases with an increase in the discharge voltage, pulse current, and pulse duration [15].

After comprehensive literature review, it has been observed that no extensive work has been carried out to study the effect of pulse on time and peak current using copper, aluminium and brass electrode materials on the Cold Work Tool Steel D2 so far. Therefore, this research paper presented the investigation of effect of various electrode materials, pulse on time and peak current on electrode materials rate using EDM of Cold Work Tool Steel D2. The above said work materials have been chosen by considering their wide range of applications in deep drawing and forming dies, cold drawing punches, hobbing, blanking, lamination and stamping dies, shear blades, burnishing rolls, master tools and gauges, slitting cutters, thread rolling & wire dies, extrusion dies etc.. The main objective of this research is to identify better electrode material which results in lowest EWR.

II. EXPERIMENTATION

A. *Materials*

The workpiece material used for this work is Cold work tool steel D2. 9 work piece of D2 of size 80x80x12.70 mm are being produced for experimental work. The material is hardened to a hardness of 62 HRC. The electrode materials are used Aluminium (Melting point 1083°C), copper and brass (Melting point 900 to 940°C).These electrodes are cylindrical in shape with a nominal diameter 22 mm.

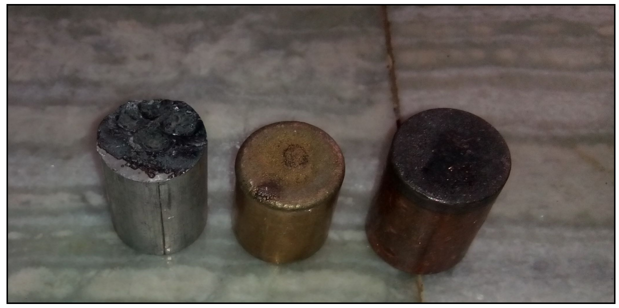

Fig.2:- Different Electrodes (copper, brass, aluminium)

B.*EDM Machine*

The machine used is SPARKONIX (INDIA) PVT.LTD die sinking EDM machine series Z 50 JM-322. The dielectric fluid used for the EDM is EDM oil. The existing dielectric circulation EDM machine needs about 160 liters of dielectric fluid in circulation. The machining is performed in commercially available dielectric fluid.

C. *PROCESS PARAMETERS*

Input Parameters

- Electrode Materials
- Peak current
- Pulse of time

Output Parameter

- Electrode Wear Rate

D.*POLARITY*

Electrode: Negative

Workpiece: Positive

E. *DESIGN OF EXPERIMENTS*

A scientific approach to plan the experiments is a necessity for conduct efficient experiments. In this research taguchi method is used. This method is a powerful experiments technique, which provides a simple, systematic and efficient approach to determine optimal machining parameters. Compared to the conventional approach to experimentation, this method reduces drastically the number of experiments that are required to model the response functions. Traditional experiment techniques involve one-factor-at-a-time experiments, where in one variable is changed while the rest are held remain constant. The major disadvantage of these techniques is that it fails to consider any possible interactions between the parameters. An interaction is the failure of one factor to produce the same effect on the response at different levels of another factor. It is also impossible to investigate all the factors and determine their main effects in a single experiment.Taguchi technique overcome all these demerits. The main effect is the average value of the response function at a particular level of a parameter. The effect of a factor level is the deviation it causes from the overall mean response. The steps involved in taguchi method are:

- Identify the response functions and the process parameters to be evaluated.
- Determine the number of levels for the process parameters and possible interaction between them.
- Select the appropriate orthogonal array and assign the process parameters to the orthogonal array and conduct the experiments accordingly.
- Analyze the experimental results and select the optimum level of process parameters.
- Verify the optimal process parameters through a confirmation experiment.

The process parameters chosen for the experiments are: (a) electrode materials (E.M.), (b) peak current (*I*p), and (c) pulse-on time (Ton), while the response functions is: (a) Electrode Wear Rate (EWR). According to the capability of the commercial EDM machine available and general recommendations of machining conditions for Cold work tool steel D2 the range and the number of levels of the parameters are selected as given in Table 1.

Table 1. Level values of input Factors

Sr. No.	Factors	Levels		
		1	2	3
1.	E.M.	Copper	Aluminium	Brass
2.	*I*p	6	18	24
3.	Ton	3	6	9

The total number of degrees of freedom needs to be found to select an appropriate orthogonal array for the experiments. The degrees of freedom are defined, as the number of comparisons that needs to be made to determine which level is better. In the present analysis does not include the interaction between parameters. Hence, there are three degrees of freedom due to three process variables. The selection of the orthogonal array is subject to the condition that the degrees of freedom for the orthogonal array should be greater than or at least equal to those for the process parameters. In the present analysis, an L9 orthogonal array with three columns and nine rows are used. This array can handle three-level process parameters and has six degrees of freedom. Therefore only nine experiments are required to evaluate the entire machining parameters using the L9 orthogonal array. The experimental layout for the machining parameters using the L9 orthogonal array is shown in Table 2.

Table 2. Taguchi L9 Orthogonal Array Design Matrix.

Expt. No.	Factor 1	Factor 2	Factor 3
E1	1	1	1
E2	1	2	2
E3	1	3	3
E4	2	1	2
E5	2	2	3
E6	2	3	1
E7	3	1	3
E8	3	2	1
E9	3	3	2

D. Experimental procedure

Experiments are performed, randomly, according to the L9 orthogonal array, on a cold work tool steel D2 plate of size 80mm×80mm×12.7 mm. For every experiment a separate an electrode is used. The depth of machining is set at 8mm for all experiments**.** The machining time is noted from the timer of the machine. The electrode wear rate is calculated by weight difference of the electrode using high precision weight machine with 80 g capacity with a precision of 0.0001g. The weight of the electrode, before and after machining is measured. The experimental results for electrode wear rate (EWR) based on L9 orthogonal array is shown in table 3.

Fig.3:- Machined Workpiece

Table 3. Experimental results for EWR

SR NO.	Process Parameter combination			Initial weight	Weight after m/cing	Weight loss	EWR
	Electrode Materials	Peak Current	Pulse On-time				
		(A)	µs	Gm	Gm	Gm	mm^3/min
1	Copper	6	3	102.14	102.06	0.08	0.11
2	Copper	18	6	102.06	101.88	0.18	0.25
3	Copper	24	9	101.88	101.84	0.04	0.06
4	Aluminium	6	6	30.17	30	0.17	0.76
5	Aluminium	18	9	28.06	26.97	1.09	4.86
6	Aluminium	24	3	25.06	24.06	1	4.46
7	Brass	6	9	93.52	87.44	6.08	8.71
8	Brass	18	3	82.98	82.52	0.46	0.66
9	Brass	24	6	78.98	73.36	5.62	8.05

III. RESULTS AND DISCUSSION

After the experimental procedure, response factor EWR was calculated from the observed data. Then a statistical analysis was performed on the calculated values and the signal to noise ratio values.

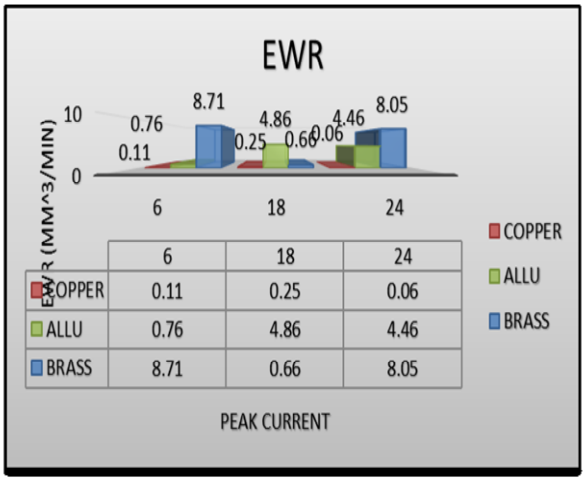

Fig. 4:- Effect of peak current on electrode wear rate

Copper electrode gives lowest electrode wear rate 0.06 mm^3/min among other two electrodes when Peak current = 24 A. Brass electrode gives highest electrode wear rate 8.71 mm^3/min among other two electrodes when Peak current = 6 A.

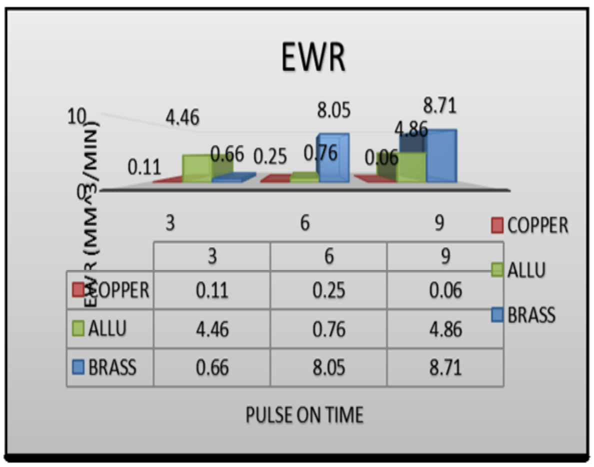

Fig. 5:- Effect of pulse on time on electrode wear rate

Copper electrode gives lowest electrode wear rate 0.06 mm^3/min among other two electrodes when 9 µs pulse on time. Brass electrode gives highest electrode wear rate 8.71 mm3/min among other two electrodes when 9 µs pulse on time.

Table 4. Optimum set of Parameter for tensile strength.

Sr.No	Electrode materials	Peak Current	Pulse on time
1.	copper	24	9

From the above table, it is conclude that Peak current play major role for EWR, among three electrodes maximum MRR and minimum electrode wear rate obtained from the copper electrodes and because from the above table it's conclude that Copper electrode material gives highest material removal rate among other two electrodes like aluminum & Brass, the reason behind it is copper electrode contain high amount of carbon that means it's have higher thermal & electrical conductivity that help to remove material from the work piece.

CONCLUSION

Copper electrode gives lowest electrode wear rate 0.06 mm^3/min among other two electrodes when Peak current = 24 A, 9 µs pulse on time. Brass electrode gives highest electrode wear rate 8.71 mm^3/min among other two electrodes when Peak current = 6 A, 9 µs pulse on time. Copper electrodes give highest MRR among three electrode when Peak current = 24 A, 6 µs pulse on time. Similarly Aluminum electrodes give lowest MRR (0.4870mm^3/min.) among three electrode when Peak current = 6 A, 6 µs pulse on time. The Electrode Wear Rate (EWR) is mainly affected by peak current (Ip) and Pulse on time (Ton) has considerable effect on EWR. For all electrodes the Electrode Wear Rate increases with increase in peak current. The Copper electrode gives the highest material removal rate. Electrode wear rate is mainly influenced by peak current (Ip) and pulse on time (Ton).The Aluminium electrode gives the poor material removal rate. Peak current and pulse on time are the most influential parameters for reducing surface quality. The optimum parameter can be considered for maximum material removal rate is obtained by copper electrode.

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