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Determination of Material Removal Rate in Electro Discharge Machining through Copper Electrode

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Abstract:** In the present manufacturing area, Electro discharge machining is one of the most emerging area for production of various components. Electro-discharge machining (EDM) is a thermoelectric process which utilizes the heat energy generated by spark to remove the material from the surface of work-piece. In the EDM process material removal takes place from both tool material and work-piece. The material removal rate depends upon the work-piece material, tool material and machining variables. Materials having low melting point having high material removal rate and hence lower surface finish. It is found that with increase in pulse current and constant pulse-on-time material removal rates increases but it affects the surface finish of material. EDM efficiency can be increased by supplying the oxygen gas between the spark gap and stack removal rate can be increased by increasing the volume of discharge crater and regular occurrence of discharges. The only limitation in the EDM is that the work-piece and the tool material both should be electrically conductive. The electrical energy converted into the thermal energy by series of the electric discharge that occurred between the work-piece and tool which are immersed into the dielectric fluid. The plasma channel is generated by thermal energy between anode and cathode. The plasma channel is generated at a temperature range of 8000-1200°C. Sometimes it is nearly about 20,000°C which is too high and can machine any material. The location of electric spark which is generated by heat energy is determined by the narrowest gap between the tool and work-piece. Duration for each spark is very short. The frequency for each spark is high as thousands sparks per second. However, spark radius is very small and the temperature in the spark zone is very high. This temperature of spark is capable for partially vaporize and melting the material from both the work-piece and tool material. The volume of material removal per discharge from the work-piece depends upon the specific applications and it is ranging from 10^{-6} - 10^{-4} mm^3. The material removed from the surface of work-piece is in the form of craters which is all overspread on the work-piece. Craters sizes are highly influenced by the value of current. Machining of Titanium alloy is carried out using EDM process. This paper presents evaluation and study of Material removal rate of titanium alloy using copper electrode in electro discharge machining process.

***Keywords:** Material removal rate, electro-discharge machining, copper electrode*

I. INTRODUCTION

There are number of EDM variations have emerged in the industries to machine the super hard alloys, composites, aerospace parts and ceramics. With the high surface finish rates and ability to machine those material which are difficult to machine by conventional machining processes. EDM is one of the earliest un-conventional machining processes. It is observed that the MRR is increasing with the pulse-on-time at all the values of current and surface quality of material starts decreasing when there is an increase in the value of pulse-on-time(1-5).Optimum values of surface roughness can be found at the lower value of pulse-on-time and current. The Effect of peak current to investigate the effect of peak current in EDM on MRR and surface roughness pulse on time varied and other parameters like pulse off time, voltage and wire feed rate kept constant. The material removal rate is low at lower values of current and it is nearly constant as the values of current are low. The material removal rate of material starts increasing with the increasing value of current. Effect of servo voltage, the effect of servo voltage on the performance of EDM is observed by varying the pulse duration and keeping all other parameters constant MRR starts increasing with increase in the servo voltage initially. But then starts decreasing with increase in the servo-voltage. On other hand surface quality of material also starts decreasing with increase in the voltage.

The major advantage of using EDM rather than conventional machining processes is very high surface finish rates(6-8). The advantage of using EDM there are no mechanical vibrations and mechanical stresses occurs during machining because of no direct contact between the work-piece and tool material and also that it can machine any profile or geometry. It can easily machine the complicated geometry which can be difficult to machine by some other machining processes(9-11). But the limitation is only the tool material and work-piece must be electrically conductive. Finishing parts of aerospace and automobile industries are machined by the EDM process.

Comparatively less research has been done in the hybridization of EDM with High-speed machining as compared to other EDM variations(12). The hybridization of HSM and EDM would give number if benefits . In present time high-speed machining has replaced use of EDM. But for deep cavities, and complicated shapes components having the internal corners and some work-piece materials which are difficult to cut, EDM is still required(13-15).

II. DETERMINATION OF MATERIAL REMOVAL RATE (MRR)

The machining is carried out on Electronica C-425 EDM set up. Titanium Alloy (Ti 6Al 4V) is used as the work material with a cylindrical copper electrode of 10 mm diameter & 80mm length & Spo oil as dielectric oil. Electro discharge machining experimental setup as shown in Fig.1

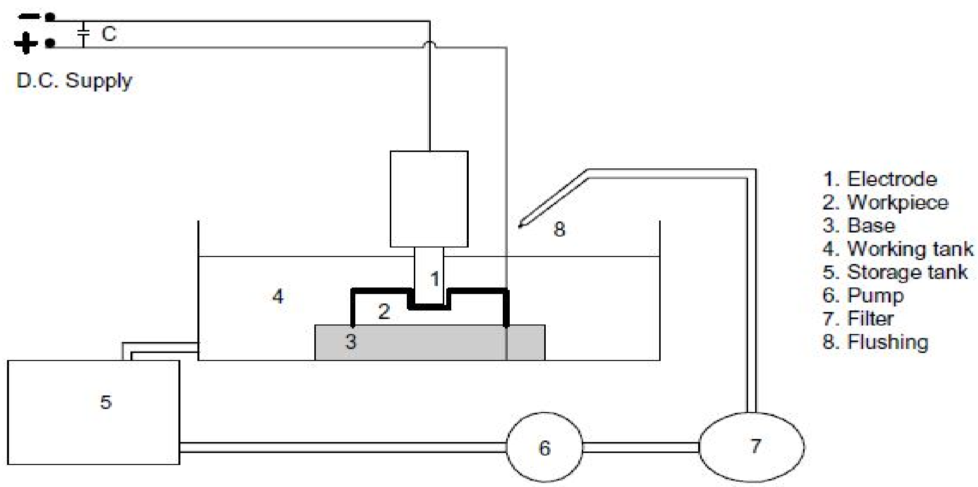

Fig.1.Electro Discharging machining process

Material properties of titanium alloy as shown in Table 1

Table 1. Physical properties for Ti-6Al-4V

Density g/cm³ (lb/ cu in)	4.42 (0.159)
Melting range °C ±15°C (°F)	1649 (3000)
Specific Heat J/Kg.°C (BTU/lb.°F)	560 (0.134)
Volume Electrical Resistivity ohm.cm (ohm,in)	170 (67)
Thermal Conductivity W/m.K (BTU/ft.h.°F)	7.2 (67)

The experiment is conducted using Taguchi method of experimental design & an appropriate orthogonal array L9 is selected after considering the design variables (Peak Current, Pulse on time, Gap).The effect of variation in input is studied on three response parameters & experimental data analyzed as per Taguchi method to find out optimum machining conditions to optimize process parameters. To attain a more accurate result, each combination of experiment was replicated three times. Changes in electrode weight, material weight and elapsed time will be recorded after each machining test. The material removal rate (MRR) is evaluated for each cutting condition by measuring the average amount of material removed and the required cutting time. The material removal rate will be estimated by their weight loss. The electrode is machined to a cylindrical shape of 10 mm diameter & 80 mm length. The material removal rate is evaluated for optimum machining conditions for this electrode.

Machining experiments for determining the optimal machining parameters is carried out by setting voltage in the range of 120-200 V, the discharge current in the range of 6.0–18.0 A, the pulse duration in the range of 30-90µs, and the Gap (Voltage between electrode & workpiece) in the range of 1-20. Essential parameters of the electrical discharge machining experiment are given in Table 2.

Table 2. Electrical discharge machining condition

Work Condition Description	
Electrode	Carbon
Workpiece	Titanium alloy(Ti 6Al4V), rectangle shape(100x90x10mm)
Input current	2-20A
Pulse on time	1-100 µs
Gap	1-20 mm
Dielectric Fluid	spo oil
Electrode materials	Copper

The experimental layout for the machining parameters using the L9 orthogonal array is used in this study. This array consists of three control parameters and three levels. In the Taguchi method, most all of the observed values are calculated based on 'the higher the better' and 'the smaller the better'. Thus in this experimental study, the observed values of material removal rate (MRR), will be set to maximum, minimum and minimum respectively. Each experimental trial will be performed with three simple replications at each set value.

III. RESULTS AND DISCUSSION

Taguchi method using design of experiments approach can be used to optimize a process. Here design of experiments approach for modeling of in EDM process is used and the various input parameters will be taken under experimental investigation and then model was prepared and finally experiments were performed. The optimization will help in improving the life of work piece, material as well as the effective and efficient working of the EDM machining process. The process parameters assignment as shown in Table 4.

Table 4. Parameter Assignment

Parameters	Level1	Level2	Level3
Peak Current(Amps)	6	12	18
Pulse on time(µs)	30	60	90
Gap(mm)	10	12	18

Material removal rate (MRR) is usually expressed in mm^3/min or gm/min which is calculated using the equation below:

$$MRR = \frac{W_b - W_a}{d * t_m} * 1000$$

where:

W_b = weight of workpiece material before machining (g)

W_a = weight of workpiece material after machining (g)

d = density of the work piece.

t_m = machining times (min)

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Evaluated and study of material removal rate (MRR) for Titanium alloy Ti-6Al-4V through electro discharge machining with consideration of various process parameters such as current, pulse on time and Gap. The effect of process parameters current, pulse on time and Gap on surface roughness of Titanium alloy Ti-6Al-4V are presented in fig 2, fig3, and fig.4.

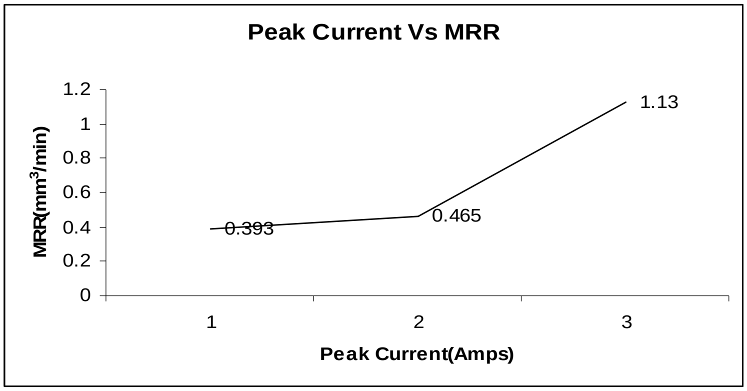

Fig.2. Influence of Current on metal removal rate

From fig.2, The metal removal rate increased with the increase in the peak current. At level 1: current 6 Amps, Metal removal rate is 0.393 mm^3/min, at level 2: current 12 Amps, Metal removal rate is 0.465 mm^3/min and at level 3: current 18 Amps, Metal removal rate is 1.13 mm^3/min. The highest metal removal rate obtained at current 18Amps and lowest metal removal rate obtained at current 6 Amps.

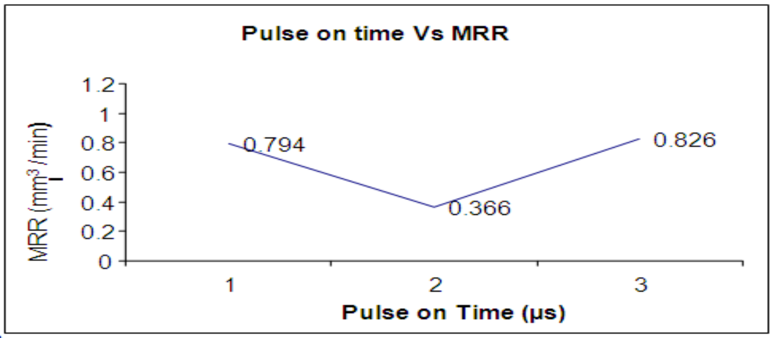

Fig. 3. Effect of Pulse on time on metal removal rate

From fig.3, The metal removal rate is decreasing with increase in pulse on time till a level 2 and after which the metal removal rate is increased with increasing in pulse on time. At level 1: Pulse on time 30 µs, metal removal rate is 0.794 mm^3/min, at level 2: Pulse on time 60 µs, metal removal rate is 0.366 mm^3/min and at level 3: Pulse on time 90 µs, metal removal rate is 0.826 mm^3/min. The highest metal removal rate obtained in titanium alloy Ti-6Al-4V at pulse on time 90 µs and lowest surface roughness obtained at pulse on time 60 µs.

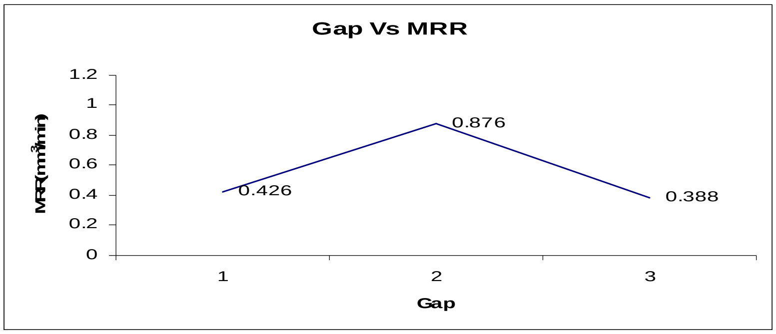

Fig.4. Effect of Gap on surface roughness

From fig.4, The metal removal rate is increasing with increase in the level of gap upto level 2, after that metal removal rate is decreasing with increasing in gap. At level 1: Gap 10mm, metal removal rate is 0.426 mm^3/min, at level 2 : Gap 12mm, metal removal rate is 0.876 mm^3/min and at level 3: Gap 18mm, metal removal rate is 0.388 mm^3/min. The lowest metal removal rate obtained in titanium alloy Ti-6Al-4V at gap of 10mm and highest surface roughness obtained at gap of 12mm.

IV. CONCLUSIONS

Conclusions are drawn from present research work as follows.

A. The lowest metal removal rate is achieved at level 2 : Pulse on time 60 µs, metal removal rate is 0.366 mm^3/min
B. The highest metal removal rate is achieved at level 3: current 18 Amps, Metal removal rate is 1.13 mm^3/min.
C. The highest metal removal rate is achieved at level 3: Pulse on time 90 µs, metal removal rate is 0.826 mm^3/min.
D. The highest metal removal rate is achieved at at level 2 : Gap 12 mm, metal removal rate is 0.876 mm^3/min
E. Finally it is observed that maximum metal removal rate is achieved at current of 18 Amps, pulse on time 90µs and Gap 12 mm.So the highest values of metal removal rate is considered for characterization and analysis of material through EDM.
F. These are the better values were obtained for metal removal rate for titanium alloy Ti-6Al-4V through electro discharge machining process.

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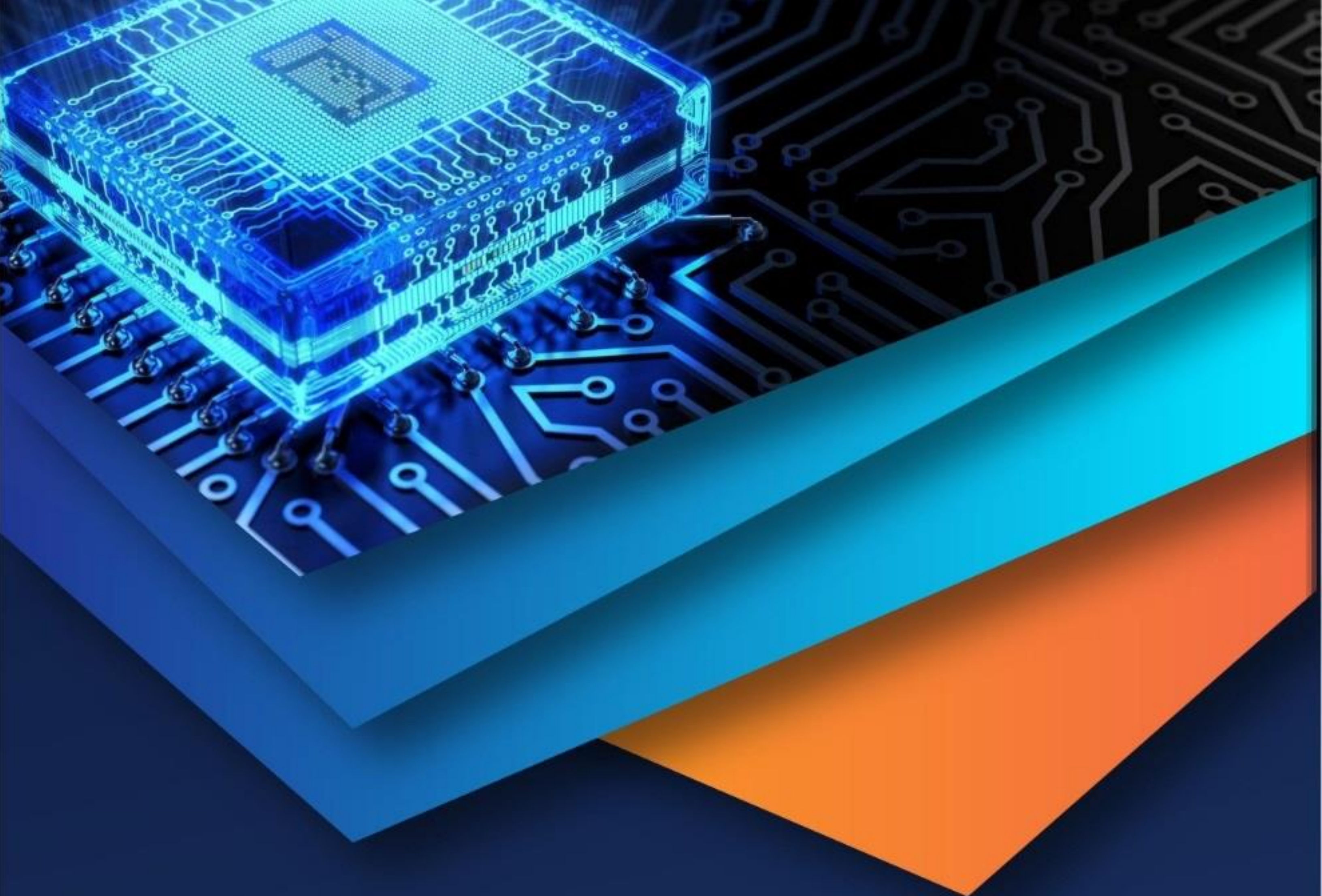

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