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Experimental Investigation Of Machining Parameters of EDM Process For Machining Ti based Alloy

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ABSTRACT:

One of the most crucial factors to consider in most manufacturing processes, and especially in those involving Electrical Discharge Machining (EDM), is the appropriate selection of manufacturing conditions. It can precisely and challengingly machine geometrically complex or hard material components, such as heat-treated tool steels, composites, super alloys, ceramics, carbides, heat-resistant steels, etc. These components are widely used in the die and mold-making industries, as well as the aerospace, aeronautics, and nuclear sectors. Ti-based alloy (Ti6Al4V), which is typically provided in a tempered and hardened state. It has a wide range of applications in medical devices, aircraft, spacecraft, premium sports equipment, and consumer electronics. It also has excellent mechanical properties and polishability. It can be found in many different places, including medical equipment, spaceships, airplanes, high-end sports automobiles, connecting rods, and consumer electronics. Because titanium alloys are resilient in high-stress engine conditions, automakers Porsche and Ferrari also employ them in their combustion engine parts. These alloys are regarded as materials that are challenging to manufacture because of their increased strength and toughness, which are known to present significant difficulties during traditional and non-conventional machining. Considering the impact of machining parameters like discharge current, pulse on time, and diameter of the cu tool material is the goal of the electric discharge machining process. Using an external flushing cylindrical cu tool. To lower the overall number of experiments, a thoughtfully crafted experimental plan was employed. The L27 orthogonal array, which is based on the Taguchi method, was used for some of the experiment. Furthermore, the variable that was most impacted by the responses of Material Removal Rate (MRR), Tool Wear Rate (TWR), and overcut (OC) was used to determine the signal-to-noise ratios connected to the experimentally measured values.

Keywords:Electrical discharge Machining (EDM); Titanium alloy; Material removal rate (MRR); Tool wear rate (TWR); Over cut (OC);

1.0 Introduction

A non-traditional method of manufacturing known as electrical discharge machining (EDM) involves repeatedly electrically discharging a tool, known as an electrode, and the part to be machined in the presence of a dielectric fluid. These discharges are produced at short intervals by electric pulse generators. EDM is currently a widely used industrial technology for high-precision machining of various metals, metallic alloys, graphite, and even some ceramic materials, regardless of their degree of hardness.Despite having outstanding mechanical and chemical qualities, titanium alloys have only been partially accepted in the field of industrial applications because of processing challenges and high manufacturing costs.

This work involved a study that was centered on die-sinking EDM of Ti-based alloys, a field of applications that is constantly expanding. As a result, a study was conducted to determine how intensity, pulse time, and duty cycle affected technological factors such overcut (OC), material removal rate (MRR), and tool wear rate (TWR) [1-4]. It is readily apparent that during the past seven years, interest in the innovative use of electrical discharge machining has grown as more people realize this technique's potential for improving process performance. It is clear that a great deal of effort has been put into improving the EDM procedure and the research into the viability of tougher materials. One of the most crucial factors to consider in the majority of manufacturing processes, and especially in procedures involving electrical discharge machining (EDM), is the right choice of manufacturing conditions[5-8]. The tool can precisely machine parts made of hard or geometrically complicated materials, including composites, super alloys, carbides, ceramics, heat-resistant steels, and titanium materials. It can also machine tools with a diameter of titanium. Utilizing an internal cleansing copper tool in the form of a circle. To lower the overall number of experiments, a carefully thought-out experimental plan was engaged.

Using the L27 orthogonal array in accordance with the Taguchi method, several experimental components were carried out. Finding out how machining parameters like discharge current and materials with higher strength and toughness affect conventional forming tools is a known difficulty in the electrical discharge machining process [9-12]. The purpose of the experiment was to determine the effects of servo voltage, current, and pulse duration on electrode wear and machining time when narrow slots in low-machining-materials were being machined using the EDM technique. Experimental observations revealed that the factors that had the greatest impact on electrode wear and machining time were pulse time and discharge current [13-16].

In EDM operation, the texture of the surface increases with increases in pulse on time and peak current but decreases with increases in dielectric fluid flow pressure [17-20].Examined the Titanium Grade 5 alloy's ability to be machined through the measurements of surface roughness (SR), tool wear ratio (TWR), and MRR. The electrode's graphite type, the tool's shape and form, the pulse current, and the pulse on and off periods represented the changeable machining factors [21-22]. Examined the optimum parameters for the process to attain lower gas emission concentrations as well as the sustainable form of EDM (wet and nearly dry EDM). When compared to wet EDM, they noted that the nearly-dry EDM procedure had decreased gaseous emission by 97% [23].Created a special electrode tool in order to get a higher caliber coating.The electrode portion of the tool is made up of a Cu electrodes component that serves as a support component and powdered NiCrBSi alloy that is used for deposition. The components are attached to one another using an electrical glue that contains metal [24-25]. Substituted for using a conventional hard electrode with EDM, a unique flexible electrode brush was created. The recently developed electrode could adjust to intricate groove sidewalls. The outcomes

shown that silver may be consistently implanted in the titanium alloy microgrooves by using an adaptable electrode pad [26-28].
This work was done using ANNOVA technique and Taguchi design of experiments (DOE). The combined use of these techniques has allowed us to create the result of MRR discharge current is most influencing factor and then pulse duration time and the last is diameter of the tool. MRR increased with the discharge current (Ip). As the pulse duration extended, the MRR decreases monotonically In the case of Tool wear rate the most important factor is discharge current then pulse on time and after that diameter of tool. In the case of over cut the most important factor of discharge current then diameter of the tool and no effect on pulse on time.

2.0 Experimental procedures: materials and methods

Electro discharge machining (EDM) is an unconventional mechanized method that uses a series of quickly occurring current discharges between a pair of electrodes in an environment of a dielectric liquid in order to remove material from the workpiece. Here, the heat produced by the spark helps remove material from the parent work piece. An electronic model of a SMART ZNC EDM machine was employed in this investigation. The cutting fluid is grade 4, tasteless and transparent EDM oil. According to two replies, surface roughness and material removal rate (MRR) have been taken into account while analyzing machining performance. Three roughness factors have been taken into consideration: the maximum height of profile (Rt), roughness height (Rz), and average surface roughness (Ra). The following phases in the experimentation technique have been followed: A computerized weighing equipment was used to determine the initial weight of each work piece. The vertical tool post was customized with a thoroughly cleaned copper rod. The task had been secured on the work piece holder.
Titanium alloy is very hard having the following Mechanical properties.

Table 1 Mechanical properties of Titanium alloy

Properties	**Values**
Tensile strength	1000Mpa
Yield stress	110 Mpa
Elongation	14-17%
Modulus	210-220 KN/mm2
Density	4.506gm/cm
Hardness	45-55 HRC

This is very hard material so it is not feasible to machine it by both conventional and non-conversional machining processes. In non-conventional machining if we select some parameters like current, pulse on time and diameter then it makes feasible to machining the material.

Cylinder shaped copper tool with internal flushing is used. Why round shaped tool is used; because we want round cavity in the work piece having diameter greater than the tool diameter.

3.0 Machining parameters

1. Diameter of tool (D)
2. Pulse duration time (Ton)
3. Discharge current

Calculations for Material removal rate (MRR), Tool wear rate (TWR), and Over cut(OC)

Evaluation of MRR;

The material MRR is expressed as the ratio of the difference of weight of the work piece before and after machining to the machining time and density of the material as shown in Eq. 1

$$MRR = \frac{Wjb - Wja}{t \times p} \qquad \text{------------ (1)}$$

Where

Wjb = Weight of work piece before machining

Wja = Weight of work piece after machining

T = Machining time = 40 mins

P = Density of Titanium alloy material = 4.506gm/cm³

Evaluation of tool wear rate;

TWR is expressed as the ratio of the difference of weight of the tool before and after Machining to the machining time. That can be explain this equations as shown in Eq. 2

$$TWR = \frac{Wtb - Wta}{Time} \qquad \text{------------- (2)}$$

Whereas

Wtb = Weight of the tool before machining.

Wta = Weight of the tool after machining.

t = Machining time (In this experiment the machining time is 40 mins).

Evaluation of over cut;

OC is expressed as half the difference of diameter of the hole produced to the toolDiameter that is shown in these equations as shown in Eq. 3.

$$OC = Djt - Dt \qquad \text{----------(3)}$$

Whereas

Djt = diameter of hole produced in the work piece

Dt = Diameter of tool

In this present work, material removal rate, tool wear rate and overcut were considered as critical parameters and varied at three levels as shown in the Table 2. The three interactions are also considered i.e. interaction between tool wear rate and material removal rate, and interaction between tool wear rate and over cut and interaction between material removal rate and over cut. Considering these factors and their interactions, L27 orthogonal array is found to be appropriate. L27 orthogonal array is shown in the Table3.

Table 2. Machining Parameters and their levels

Machining Parameters	Symbol	Unit	Levels		
			1	2	3
Electrode diameter	(D)	mm	10	8	6
Spark on time	(Ton)	μs	256	1024	4096
Discharge current	(Ip)	A	3.5	4.5	5.5

Table 3. L27 Orthogonal Array

S.No.	Diameter	Current	Spark on time
Unit	mm	A	μs
1	10	3.5	256
2	10	4.5	256
3	10	5.5	256
4	10	3.5	1024
5	10	4.5	1024
6	10	5.5	1024
7	10	3.5	4096
8	10	4.5	4096
9	10	5.5	4096
10	8	3.5	256
11	8	4.5	256
12	8	5.5	256
13	8	3.5	1024
14	8	4.5	1024
15	8	5.5	1024
16	8	3.5	4096
17	8	4.5	4096
18	8	5.5	4096
19	6	3.5	256
20	6	4.5	256
21	6	5.5	256
22	6	3.5	1024
23	6	4.5	1024
24	6	5.5	1024
25	6	3.5	4096
26	6	4.5	4096
27	6	5.5	4096

Experimental were conducted according to Taguchi method by using the machining set up and the designed Round –shaped electrodes with internal flushing. The control parameters like diameter of electrode (D), discharge current (Ip), and pulse duration (Ton) conductivity were varied to conduct 27 different experiments and the weights of the work piece and Tool and dimensional measurements of the cavity were taken for calculation of MRR,TWR,OC.

4.0 SIGNAL TO NOISE RATIO:

In Taguchi method, a loss function is defined to calculate the deviation between the experimental value and the desired value. Usually, there are three categories of the quality characteristic in the analysis of the signal-to-noise ratio, i.e. the lower-the-better, the larger-the better, and nominal-the-better. The signal-to-noise ratio can be expressed as shown in Eq. 4

S/N = -10 log10 (1/n (∑ yi-2)) ------------ (4)

Where,

n number of repetition in a trial

yi weld strength for ith trial

Since the experimental design is orthogonal, it is possible to separate out the effect of each Design parameter at different levels.

5.0 RESULT AND DISCUSSION:

In this chapter are related about in fluencies of MRR, TWR, and OC and finding the result which factors discharge current, pulse duration, diameter of Cutout, is most important with the help of Taguchi method

Response table for TWR, MRR, OC shown in the table4for given input parameters.

Table 4 Response table for TWR, MRR, OC

S.NO	Diameter	Discharge current	Spark on time	MRR	TWR	OC
Unit	Mm	A	μs	(mm^3/min)	(gm/min)	(mm)
1	10	3.5	256	.00145	.00040	.86200
2	10	4.5	256	.00084	.00032	.69650
3	10	5.5	256	.00068	.00025	.86800
4	10	3.5	1024	.00276	.00037	.94100
5	10	4.5	1024	.00110	.00020	.87150
6	10	5.5	1024	.00075	.00040	.72250
7	10	3.5	4096	.00189	.00075	.82400
8	10	4.5	4096	.00118	.00175	.72950
9	10	5.5	4096	.00076	.00175	.83700
10	8	3.5	256	.00153	.00530	.64400
11	8	4.5	256	.00146	.01107	.67150
12	8	5.5	256	.00106	.02345	.77200
13	8	3.5	1024	.00279	.00437	.71200
14	8	4.5	1024	.00250	.01000	.97700
15	8	5.5	1024	.00230	.00092	.69650
16	8	3.5	4096	.00216	.01062	.73810
17	8	4.5	4096	.00182	.02250	.68720
18	8	5.5	4096	.00185	.01660	.72250
19	6	3.5	256	.00168	.00155	.57150
20	6	4.5	256	.00111	.00237	.54450
21	6	5.5	256	.00086	.00250	.53550
22	6	3.5	1024	.00021	.00250	.57940
23	6	4.5	1024	.00203	.00137	.56530
24	6	5.5	1024	.00189	.00250	.57210
25	6	3.5	4096	.00152	.00137	.59000
26	6	4.5	4096	.00156	.00277	.56800
27	6	5.5	4096	.00137	.00940	.01210

Influence on MRR

S/N = -10 log10 (1/n (∑ yi-2)

Where, n number of experiment

yi for ith experiment

Response Table 5 for Signal to Noise Ratios

Larger is better

Level	Diameter(mm	Current(A	Spark on time(µs)
1	-58.61	-58.88	-56.5
2	-54.57	-56.73	-56.86
3	-58.86	-56.44	-58.68
Delta	4.29	2.45	2.18
Rank	1	2	3

During the process of Electrical discharge machining, the influence of various machining parameter like Ip, Ton and Diameter of tool has significant effect on MRR, as shown in the main effect plot for S/N ratio of MRR in the Fig1.

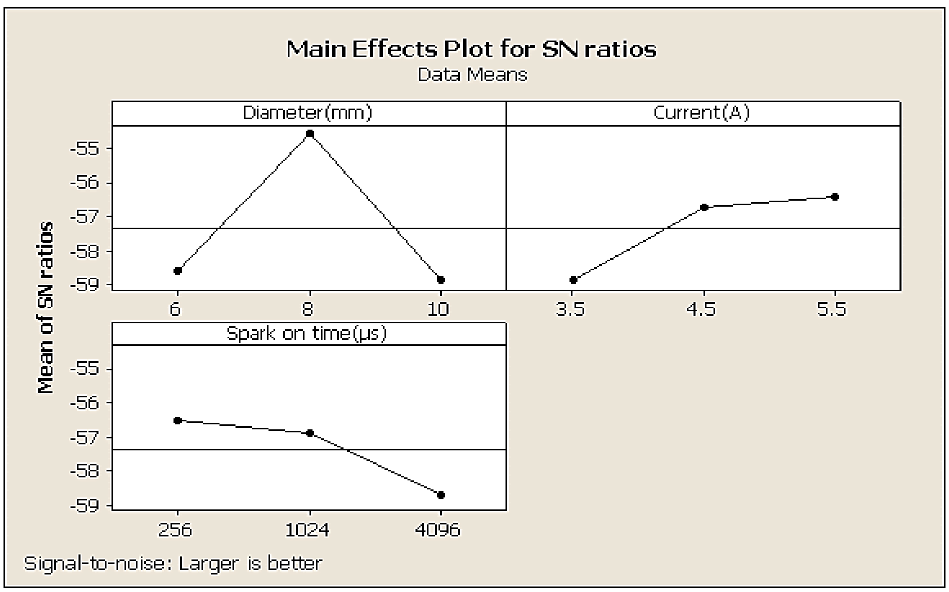

Fig. 1 Main effects plot for MRR

The diameter of the tool has no significant effect on MRR. The interaction plot of MRR is shown in Fig.2, where each plot exhibits the interaction between three different machining parameters like Ip, Ton and dia. of tool.

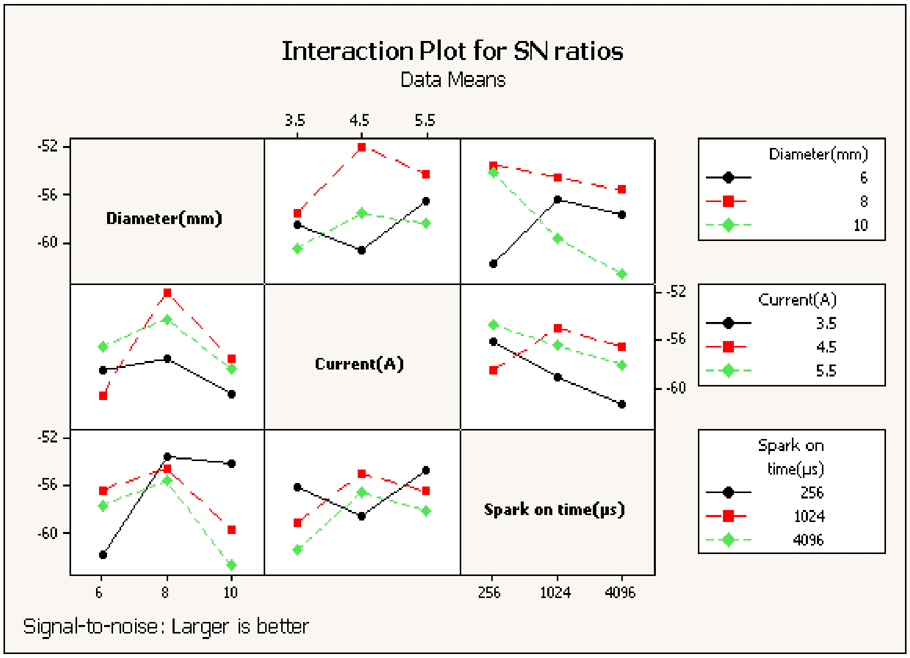

Fig. 2Interaction plot for MRR

Analysis of Material Removal Rate

As shown in graph fig 3Í(a) that as the current increases MRR improve up to 5.5 amperes and then decrease. Pulse on time is 50 µs. This can be explained as initially with increase in current MRR increase because of higher erosion of work piece material with increase in current. Thereafter with future increase in current net deposition on work piece material from metallurgical tool electrode take place. This explains the decrease in MRR.

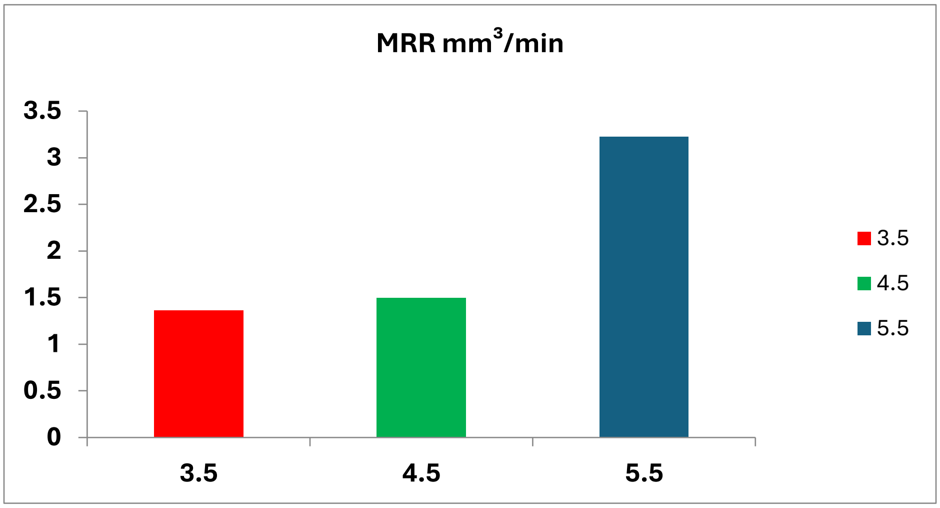

Fig. 3 MRR for current

Line chart for MMR with current Ip(pulse on for 256μs)

As shown in graph fig 4 when the pulse on is kept 1024μs as the current is increase there is slowly improvement in MRR and after then increase faster this is because as the MRR is decrease with increase in pulse on time. In graph see carefully the value of MRR is more than the value of MRR is graph.

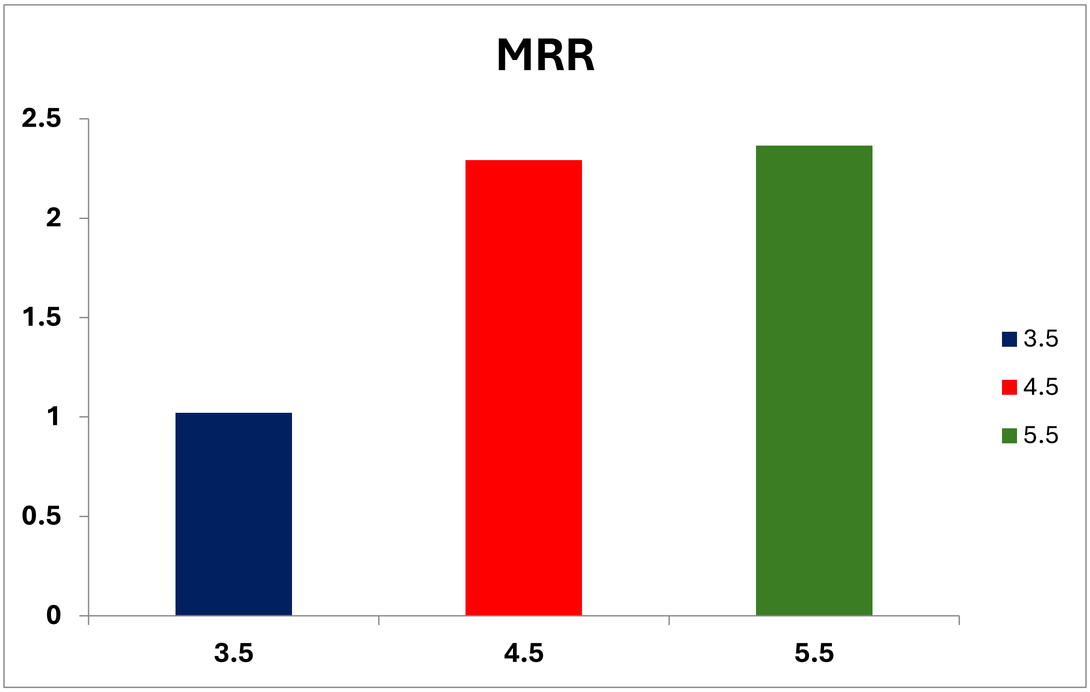

Fig 4 Line chart for MMR with current Ip(pulse on for 256μs)

In graph fig 5 MRR is increase with current but at current 5.5A the MRR decrease. This is due to the net deposition on work piece material from metallurgy tool electrode. Pulse duration is 4096μs

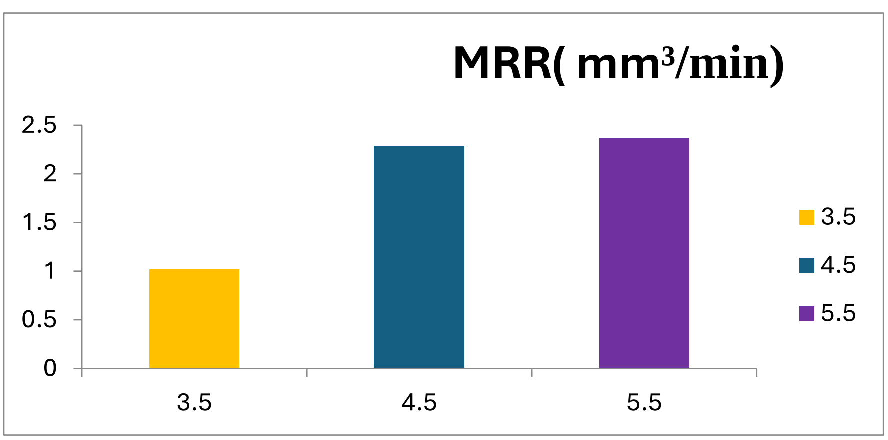

Fig 5Line chart for MMR with current Ip (pulse on for 4096μs)

Influences on TWR

The S/N ratio for TWR are calculated as given in equation 5.2 Taguchi method is used to analysis the result of response of machining parameters for smaller is better

S/N = -10 log10 (1/n (∑ yi-2))…………… (5.2)

Where, n number of repetition in a trial

yi weld strength for ith trial

During the process of Electrical discharge machining, the influence of various machining parameter like Ip, Ton and Diameter of tool has significant effect on TWR, as shown in main effect plot for S/N ratio of MRR in the Fig 5.3

Response Table 6 a for Signal to Noise Ratios

Smaller is better

Table 6Responsefor Signal to Noise Ratios

Level	Diameter(mm	Current(A	Spark on time(µs)
1	52.33	54.19	55.18
2	41.46	57.74	52.42
3	65.89	47.75	52.07
Delta	24.43	9.99	3.11
Rank	1	2	3

The diameter of the tool has no significant effect on TWR. The interaction plot of MRR is shown in the Fig 6 & Fig 7, where each plot exhibits the interaction between three different machining parameters like Ip, Ton and dia. of tool

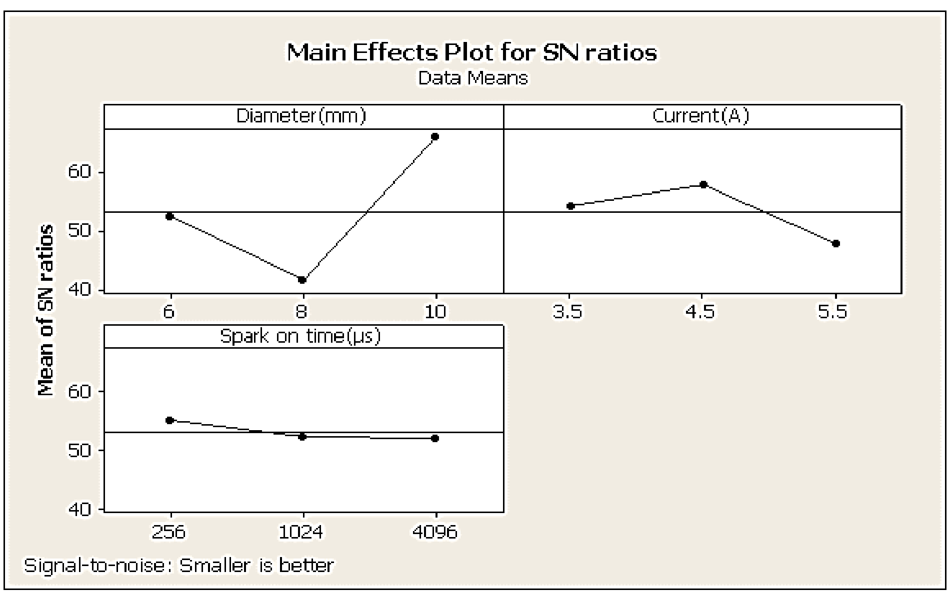

Fig. 6 Main effects plot for TWR

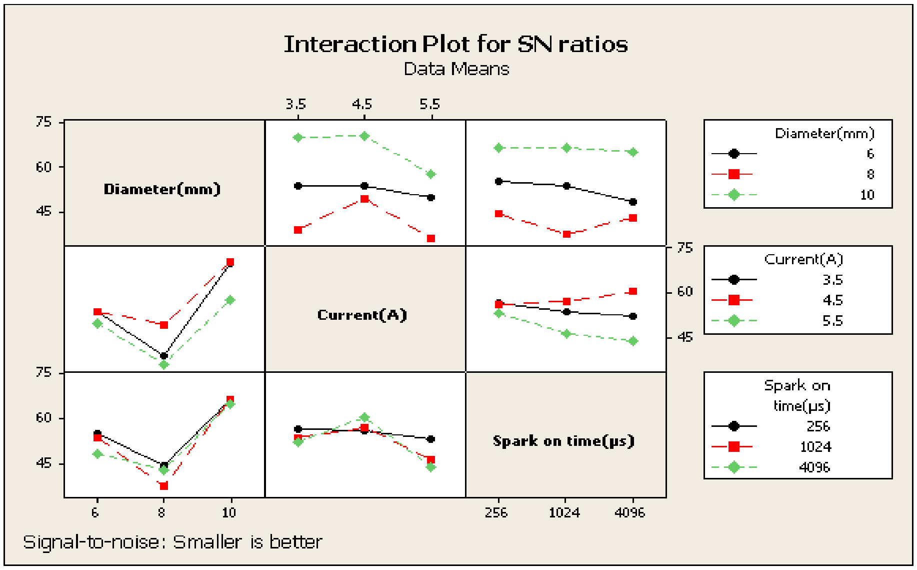

Fig. 7 Interaction plot for MRR

Analysis of tool wear rate Current

Increase in the discharge current from 3.5 to 4.5 A the tool wear rate is decreasing , but decrease current in the range of 4.5 to 5.5 A tool wear rate is increase . Because of Ip increase the pulse energy increase and thus more heat energy is produced in the tool work piece interface, lead to increase the melting and evaporation of the electrode. As show in graph fig 8,9and 10

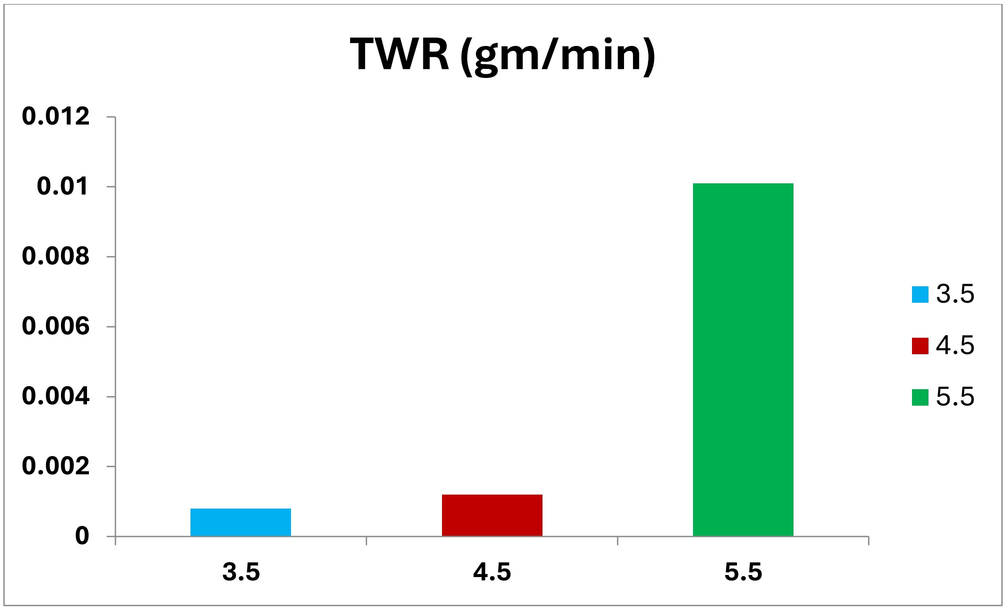

Fig 8 Line chart for TWR with current Ip (pulse on for 256µs)

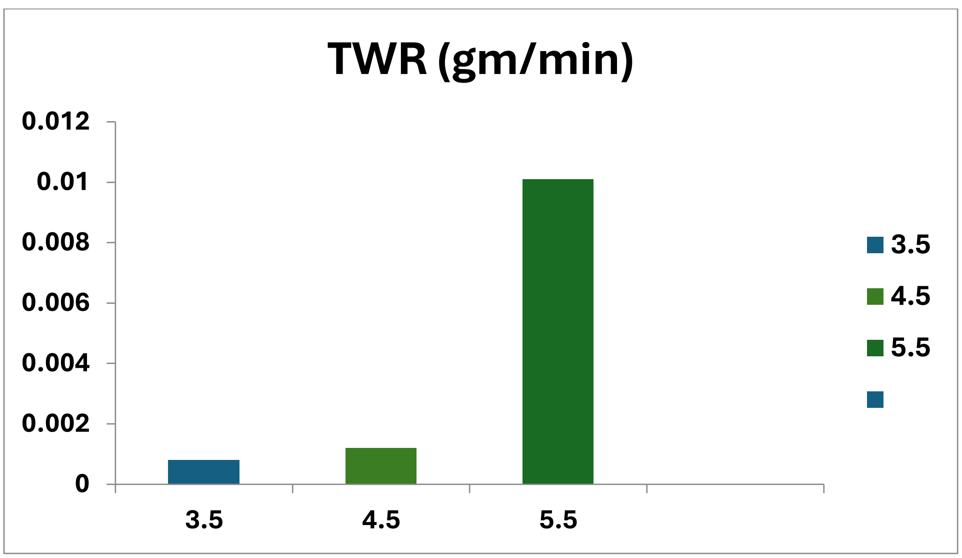

Fig 9 Line chart for TWR with current Ip (pulse on for 1024µs)

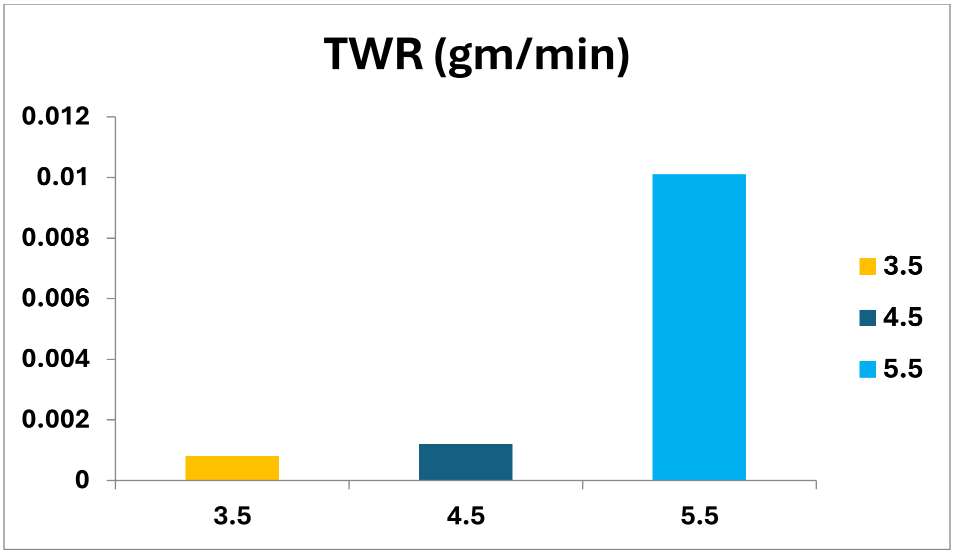

Fig 10 Line chart for TWR with current Ip (pulse on for 4096µs)

Influences on OC

The S/N ratio for OC are calculated as given in equation 4.2 Taguchi method is used to analysis the result of response of machining parameters for smaller is better The over cut are effect to each parameter such as diameter of tool, discharge current and pulse on time, the main effect plot for S/N ratios shown in the Fig 11 for over cut. The interaction plot of OC is shown in the Fig 12 where each plot exhibits the interaction between three different machining parameters like Ip Ton and dia. of tool. This implies that the effect of one factor is dependent upon another factor

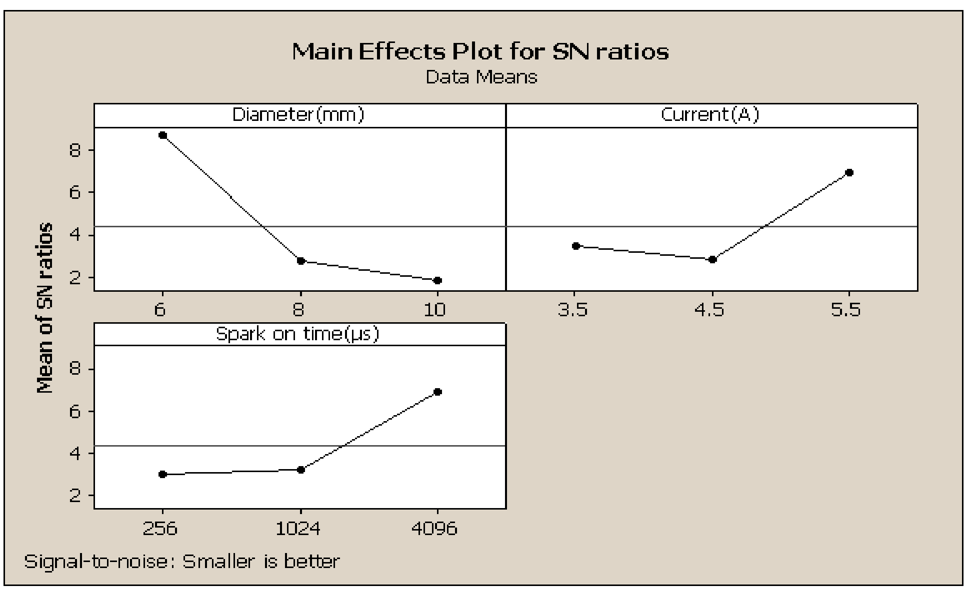

Fig 11 Main effects plot for OC

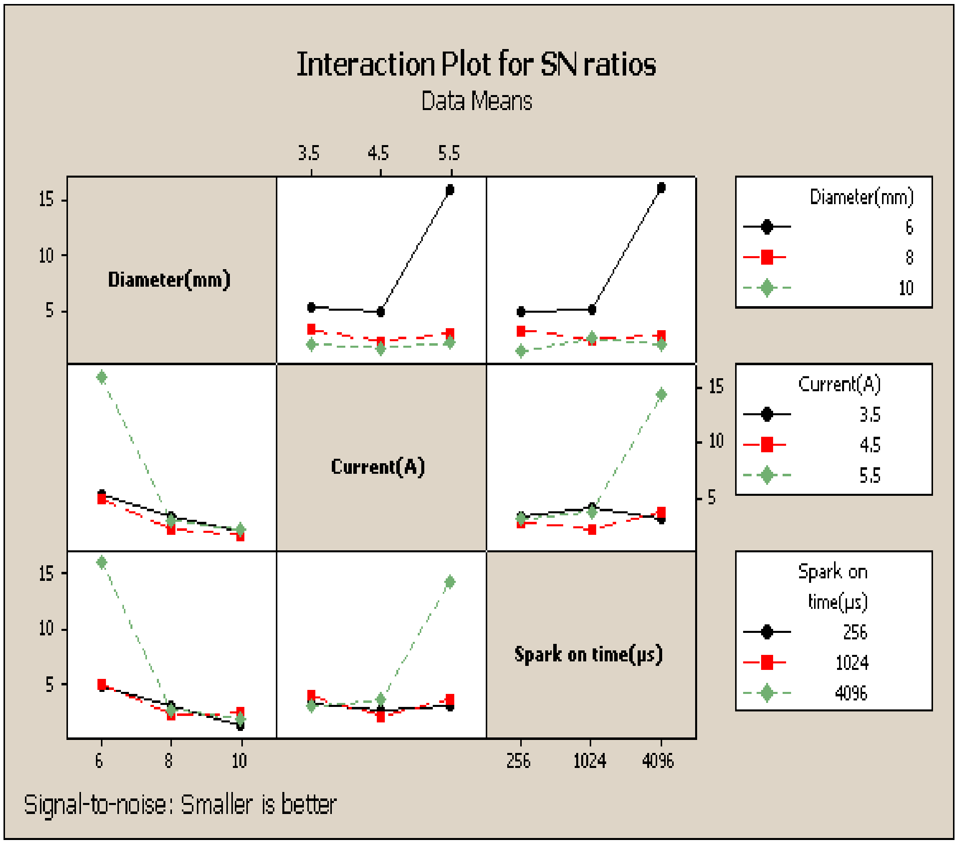

Fig 12 Interaction plot for MRR

6.0 CONCLUSION

In the present work of study on the effect of machining response are MRR, TWR, and OC of Ti6al4v using cylindrical cu tool with external flushing system tool have been investigated for EDM process. The experiments were conducted under various parameters setting tool diameter(D), discharge current (Ip), pulse on time (Ton) L-27 OA based on Taguchi design was performed for Minitab software was used to analysis the result.

(a). Finding the result of MRR discharge current is most influencing factor and then pulse duration time and the last is diameter of tool. MRR increased with the discharge current (Ip). As pulse duration is extended, the MRR decrease monotonically

(b). In the case of Tool wear rate the most important factor is discharge current then pulse on time and after that diameter of tool.

(c). In the case of over cut is more important factor of discharge current then diameter of the tool and no effect on time.

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Declarations

Conflict of interest: The authors declare that they have no conflict of interest.

Consent to Participate: Additional informed consent was obtained from all individual participants for whom identifying information is included in this chapter.

Consent to Publish: The authors consent to publish this article in this journal if it is accepted.

Ethical Approval: The authors declare that any part of the work is copied from others and is an original research work.

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