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Research paper

Comparative Study on EDM of Ti-6Al-4V Using Circular and Convex Shaped Electrodes

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Abstract

As on today, Electrical Discharge Machining (EDM) is world famous unconventional machining process for electrically conductive materials. In this project work, Ti-6Al-4V is performed in electrical discharge machining using differently shaped (circular and convex) copper electrode. The machining parameters considered are the pulse on- time, pulse off-time, voltage and current to investigate machining characteristics like material removal rate and tool wear rate. Taguchi method is applied to frame experimental design. Ti-6Al-4V finds wide usage in industrial applications such as marine, aerospace, bio-medical and so on.

***Keywords**: EDM; Taguchi Analysis; Ti-6AL-4V.*

1. Introduction

EDM is known unconventional machining process for extremely tough and electrically conductive materials. Ti-6Al-4V is one of the tough, hard and high strength material which goes with enormous usage in high-tech industries. The machining of this material by conventional machining processes takes a long time. To overcome this pitfall, the EDM is suitably selected. In EDM, the copper is an ideal tool for a long time due its availability, cost, and other physical & mechanical properties. In this project, we have studied the reputed papers under Ti-6Al-4V with different electrode materials. The main few literature papers are noted below.

Hascalik et al examined various electrodes graphite, copper and aluminium while machining in EDM. The authors conclude the graphite electrodes provides higher material removal rate among other electrode materials [1]. Pradhan et al studied titanium super alloy in micro EDM for overcut. The peak current and pulse on time is greatly dominated by the overcut [2]. The authors studied EDM input parameters for better MRR, lower TWR and lower SR using desirability approach and fuzzy modelling to save the cost of machining [3]. Noor et al reported a paper in EDM of Ti-6Al-4V for tool wear rate (TWR) [4]. Sarkar et al documented the EDM of titanium superalloy using ANOVA method [5]. Ozgedik et al documented EDM performance characteristics such as wear at edge & front, MRR, TWR, relative wear, surface roughness [6]. Garg et al coined EDM for improving material removal rate [7]. Morales et al studied EDM of D2 tool steel with two different electrode materials [8]. Lin et al pointed out the MRR maximum when using the dielectric fluid as distilled water than the kerosene [9].

From the literature, there is lack of work noticed for changing the shape of electrodes. In this paper, comparative study of copper electrodes of circular and convex shape was investigated for material removal rate and tool wear rate.

2. Experimental Setup and Procedure

A Pictorial view of Electric Discharge machining of model ELEKTRA PS 50 is shown in figure 1. In this paper, workpiece material is Ti-6Al-4V and electrode material is copper. Both workpiece and electrode materials ordered more than required dimensions and cut into the required size for performing machining. The different machining parameters such as current, voltage, pulse on-time, and pulse off-time are selected at various levels (indicated in table 1) in order to find two performance characteristics like material removal rate (MRR) and tool wear rate(TWR).

The electric discharge machining is done based on the L9 orthogonal array (displayed in table 2). The weight of the workpiece is calculated before machining and after machining for calculating the MRR using the equation number 1. In the same manner, each electrode weight is measured before machining and after machining for calculating the TWR using the equation number 2.

Removal Rate = Mass / (Time*Density) in mm^3/min (1)

Mass = (difference in Weight of Workpiece or Electrode before machining after machining) in grams
Time = Machining time in minutes

Fig.1: Electric Discharge Machining

Table 1: Machining Parameters

Levels	Current (I)	Voltage (V)	Pulse on-time (Ton)	Pulse off-time (Toff)
Low (1)	5	30	11	5
Mid (2)	10	60	29	7
High (3)	15	90	34	9

Table 2: Taguchi L9 Orthogonal Array

Run	Process Parameters			
	Current (I)	Voltage (V)	Pulse on-time (Ton)	Pulse off-time (Toff)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 3: Experimental Observations

Run	Circular Shaped Electrode		Convex Shaped Electrodes	
	Material Removal Rate (mm^3/min)	Tool Wear Rate (mm^3/min)	Material Removal Rate (mm^3/min)	Tool Wear Rate (mm^3/min)
1	0.6877	0.1263	0.4072	0.1219
2	0.9230	0.0078	0.7760	0.0111
3	0.3619	0.0033	0.1764	0.0100
4	0.0271	0.0167	0.0036	0.0100
5	1.5542	0.0749	1.3280	0.0425
6	0.7737	0.1364	0.4977	0.1085
7	0.0036	0.0279	0.0012	0.0022
8	0.2850	0.0324	0.6357	0.1196
9	1.0429	0.0659	0.5520	0.0302

3. Results and Discussions

The material removal rate and tool wear rate for circular and convex shaped electrodes in EDM of Ti-6Al-4V is coined in table 3. It is from the table 3, highest MRR of 1.5542 mm^3/min is obtained for circular shaped electrode on the other hand 1.3280 mm^3/min is obtained for convex shaped electrode. The minimum TWR of 0.0033 mm^3/min is found for circular shaped electrode and 0.0012 mm^3/min is figured for convex shaped electrode respectively. With this finding the circular shaped electrode provides higher TWR than the convex shaped electrode in EDM. The figure 2 and figure 4 illustrates the main effects plot for MRR and TWR of circular shaped electrodes. The table 4 and table 6 display the response table for MRR and TWR of circular shaped electrodes. The figure 3 and figure 5 authenticates the main effects plot for MRR and TWR of convex shaped electrodes. The table 5 and table 7 display the response table for MRR and TWR of convex shaped electrodes

3.1. Analysis of MRR

Fig. 2: MRR for circular shaped electrode

From figure 2 the MRR get higher value with increasing the current, voltage and pulse on-time from low level (1) to mid-level (2) and after from mid-level (2) it does not raise starts decreasing. But the reverse effect is viewed for pulse off-time, the increases in pulse off-time decrease the MRR. The table 4 confirms the pulse off-time is the most influencing parameter and it is ranked first for achieving higher MRR.

Table 4: Response Table for MRR - Circular Shaped Electrode

Levels	I	V	Ton	Toff
Low (1)	0.6575	0.2395	0.5821	1.0949
Mid (2)	0.7850	0.9207	0.6643	0.5668
High (3)	0.4438	0.7262	0.6399	0.2247
Delta	0.3412	0.6813	0.0822	0.8703
Rank	3	2	4	1

From figure 3 the MRR get higher value with increasing the current and pulse on-time from low level (1) to mid-level (2) and after from mid-level (2), it starts decreasing. The pulse on-time increases with increases in MRR. But for the reverse effect is seen for pulse off-time, by rising pulse off-time MRR get a lower value.

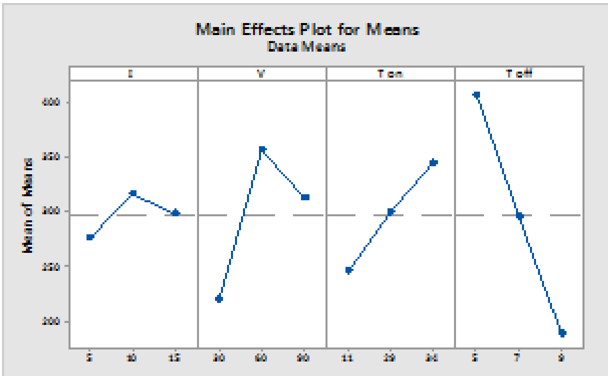

Fig.3: MRR for convex shaped electrodes

The table 5 also confirms the pulse off-time is the most influencing parameter and it is ranked first for achieving higher MRR.

Table 5: Response Table for MRR – Convex Shaped Electrode

Levels	I	V	Ton	Toff
Low (1)	275.8	220.3	246	407
Mid (2)	316.7	357.3	300	296
High (3)	298.7	313.5	345.2	188.2
Delta	40.8	137	99.2	218.8
Rank	4	2	3	1

3.2. Analysis of Tool Wear Rate

From figure 4, TWR increases with increasing the current from a low level (1) to mid-level (2) and after from mid-level (2), it starts decreases. Voltage and pulse on-time decreases with increasing from a low level (1) to mid-level (2) and after from mid-level (2), it starts increasing. The increases in pulse off-time TWR start decreasing. The table 6 verifies pulse off-time is the best machining parameter for achieving minimum TWR.

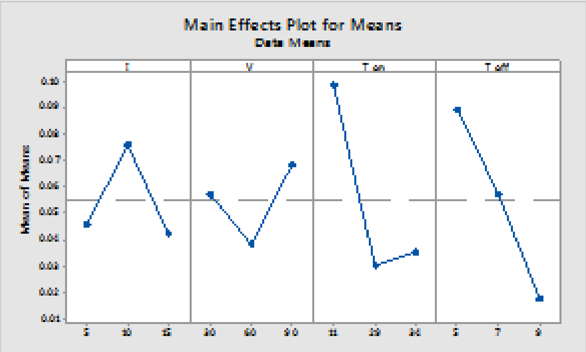

Fig.4: TWR for circular shaped electrode

Table 6: Response Table for TWR - Circular Shaped Electrode

Levels	I	V	Ton	Toff
Low (1)	0.04580	0.05697	0.09837	0.08903
Mid (2)	0.07600	0.03837	0.03013	0.05737
High (3)	0.04207	0.06853	0.03537	0.01747
Delta	0.03393	0.03017	0.06823	0.07157
Rank	3	4	2	1

TWR for convex shaped electrode is figured in figure 5. TWR get high value with increasing the current and voltage from a low level (1) to mid-level (2) and after from mid-level (2), it starts decreasing. pulse on-time and pulse off-time decrease with increasing from low level (1) to mid-level (2) and after from mid-level (2) it starts increasing slightly for pulse on-time than the pulse off-time.

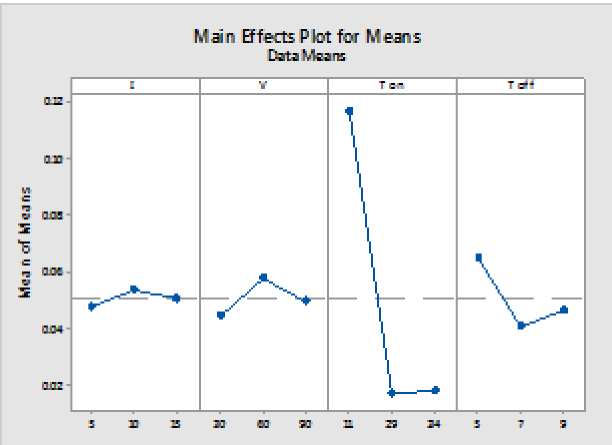

Fig.5: TWR for convex shaped electrode

Table 7 shows response table for convex shaped electrode. The minimum TWR depends on the machining parameters in that order of pulse on-time, pulse off-time, voltage, and current.

Table 7: Response Table for TWR – Convex Shaped Electrode

Levels	I	V	Ton	Toff
Low (1)	0.04767	0.0447	0.11667	0.06487
Mid (2)	0.05367	0.05773	0.0171	0.0406
High (3)	0.05067	0.04957	0.01823	0.04653
Delta	0.006	0.01303	0.09957	0.02427
Rank	4	3	1	2

4. Conclusion

The comparative study of circular and convex shaped electrodes is studied in EDM of Ti-6Al-4V using Taguchi Method. The following conclusions are drawn considering mainly current (I), voltage (v), pulse on-time (Ton) and pulse off-time (Toff) as important machining parameters, for knowing two different performance characteristics like MRR and TWR.

Optimum Setting for Circular Shaped Electrodes:
MRR – I: 10 A V: 60 V Ton: 29 µs Toff: 5 µs
TWR – I: 15 A V: 60 V Ton: 29 µs Toff: 9 µs
Optimum Setting for Convex Shaped Electrodes:
MRR – I: 10 A V: 60 V Ton: 34 µs Toff: 5 µs
TWR – I: 5 A V: 30 V Ton: 29 µs Toff: 7 µs

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