Optimization of Micro Electrical Discharge Machining Parameters of Ti-6Al-4V

Rajkumar P[1] Muralidharan S[2] Nagendiran B[3] Parthipan M[4] Sivanantham K[5]
[1,2,3,4,5]Assistant Professor
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Muthyammal Engineering College, Rasipuram, Namakkal, India

Abstract— Electrical Discharge Machining (μEDM) appears to be very promising as a future micromachining technique since in many areas of applications it offers several advantages. Brass (500μm) electrode is used as tool and Ti-6Al-4V is used as work piece. Different parameters, such as the Current, Pulse on time and Pulse off time are used to get the aperture's size. Dielectric is De-ionized water. In μEDM setup, the dielectric flow circulating system is essential and must be considered carefully, otherwise the dirty dielectric will flow into the machining chamber again and cause second discharging of the work piece and infect the aperture's sizes. Because the Brass electrode is too small, a use current passing will destroy the Brass electrode. Analysis indicates the most effective zone of predominant process parameters such as Current, Pulse on time and Pulse off time which give the appreciable amount of Material Removal Rate (MRR) with less Over Cut (OC). The experimental results and analysis on μEDM will open up more application possibilities for μEDM. This result shows the Current play an important part in the MEMS.

Key words: Micro-EDM, De-ionized water, Ti-6Al-4V

I. INTRODUCTION

Ti-6Al-4V is a high strength, low weight and exceptional corrosion conflict and it's used to aerospace, automobile, chemical plant, power generation, oil and gas extraction, surgical instruments, and other major industries. The physical properties are high tensile strength, low thermal conductivity. Again, the property like strong alloying tendency or chemical reactivity of Ti-6Al-4V with most tool materials, which causes rapid destruction of the cutting tool with galling, welding and smearing at the interacting surface, leads to excessive chipping and/or premature tool failure and poor surface finish[1].

Recently, there has been an increasing demand for micro-machining due to the reduction in size and weight of technological devices [2]. Although electro-discharge machining (EDM) has great advantages for machining work pieces with special shape, regardless of material strength or hardness, the machining efficiency of EDM is lower compared to traditional machining processes [3].Its applications are production of complicated and irregular shaped profiles, thread cutting in jobs, drilling of micro holes, helical profile drilling, curved hole drilling.

II. EXPERIMENTAL SETUP AND METHODOLOGY

A. Materials:

The tool material used was Brass tool of 500μm diameter. The workpiece material used was Ti-6Al-4V and Table 1and 2 show the chemical compositions and physical as well as mechanical properties of titanium alloy (Ti-6Al-4V), respectively. The dielectric fluid used was De-ionized water having relatively high flash point, high auto-ignition temperature and high dielectric strength.

B. Machine Tool:

Experimental results were performed using a Electronica Electrical Discharge Machine, Series-BSR 5030. Work tank interval dimension is 1110mm (W) x 660mm (D) x400mm (H). Longitudinal travel (X) is 400mm. Transverse travel (Y) is 300mm. Maximum Tank capacity is 425 liters. Maximum workpiece weight is 1000kg and maximum workpiece height is 250mm.

C. Planning For Experimental Analysis:

The experimental layout for the machining parameters using the L_{16} orthogonal array was used. This array consists of three parameters and four levels. An orthogonal array gives a more reliable estimate of the factor effects with fewer tests compared to traditional methods. The process parameters along with their values at three levels are given in Table 3.

The number of degrees of freedom was calculated from the number of parameters identified and their number of levels of variation. 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 study, the values of MRR was maximum and OC was minimum respectively.

Elements	Weight in %
Carbon	0.01
Nitrogen	0.006
Iron	0.18
Aluminum	6.22
Vanadium	4.04
Oxygen	0.20
Yttrium	50 PPM
Hydrogen	59 PPM
Titanium	Balance

Table 1: Compositions of Ti-6Al-4V

Property	Typical Value
Density (g/cm^3)	4.42
Melting range (°C±15°C)	1650

Specific heat (J/Kg °C)	560
Ultimate strength (KSi)	162.7-164.3
0.2% Yield strength(KSi)	153.7-154.9
% Elongation (inches)	9.3-12.0

Table 2: Properties of Ti-6Al-4V

Design of experiments is a powerful analysis tool for modeling and analyzing the influence of process variables over some specific variable, which is an unidentified role of these process variables. The most important stage in the design of experiment lies in the selection of the control factors. Combining the experiment design theory and the quality loss function concept first proposed by Taguchi in the 1960s is widely used to solve and improve industrial product quality and reliability. In order to observe the influence degree of control factors (feed rate, spindle speed and drill diameter) in drilling, three factors and three levels are considered. Namely, a L_{16} orthogonal array was employed. The array chosen was the L_{16}, which have sixteen rows corresponding to the number of tests with three columns at four levels, as shown in Table 3. The factors and the interactions are assigned to the columns.

Ex .No	Current (Amp)	T_{on} (µs)	T_{off} (µs)
1	2	20	10
2	2	40	30
3	2	60	70
4	2	80	90
5	3	20	10
6	3	40	30
7	3	60	70
8	3	80	90
9	4	20	10
10	4	40	30
11	4	60	70
12	4	80	90
13	6	20	10
14	6	40	30
15	6	60	70
16	6	80	90

Table 3: L_{16} orthogonal array

III. OPTIMIZATION

A. *Signal to Noise:*

Signal to noise is a measure of the amount of observed variation present relative to the observed average of the data. To optimize the machining parameter of EDM with respect to the performance character is MRR. The objective function in this study is to obtain the larger the better characteristics on unevenness, the ratio of signal-to-noise (S/N ratio) defined according to the Taguchi method as follows:

$$\frac{S}{N} = -10\log\frac{1}{n}\sum_{i=1}^{n} 1/yi^{2} \quad (1)$$

The objective function in this study is to obtain the smaller the better characteristics on unevenness, the ratio of signal-to-noise (S/N ratio) defined according to the Taguchi method as follows:

$$\frac{S}{N} = -10\log\frac{1}{n}\sum_{i=1}^{n} yi^{2} \quad (2)$$

B. *ANOVA:*

Analysis of variance (ANOVA) is a technique that will enables us to test for the significance of the difference among more than two sample means. Analysis of variance is useful, for determining whether the mean qualities of outputs of various machines differ significantly.

Analysis of variance (ANOVA) is a statistically based, objective decision-making tool for noticing any differences in the average performance of groups of items tested. ANOVA helps in officially testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels. This is accomplished by separating the total variability of the Signal to noise ratios, which is measured by the sum of the squared deviations (SD) from the total mean S/N ratio, into helps by each of the design parameters and the error.

$$\text{MRR} = \frac{\text{IW} - \text{FW}}{(\rho * t)}\ \frac{\text{mm3}}{\text{min}} \quad (3)$$

Changes in electrode weight, material weight and elapsed time were recorded after each machining test. The MRR and the OC were evaluated for each cutting condition by measuring the average amount of material removed and the required cutting time.

CURRENT (AMP)	PULSE ON TIME (µS)	PULSE OFF TIME (µS)	MRR (mm^3/min)	S/N(dB) FOR MRR
1	1	1	1.4641	3.311415
1	2	2	1.0947	0.785902
1	3	3	1.2806	2.14827
1	4	4	2.3723	7.503392

2	1	1	1.505	3.55073
2	2	2	5.51	14.82303
2	3	3	1.0055	0.047641
2	4	4	1.9532	5.814934
3	1	1	3.6854	11.32969
3	2	2	1.9504	5.802474
3	3	3	5.2434	14.39226
3	4	4	3.3937	10.61347
4	1	1	6.936	16.82218
4	2	2	7.4821	17.48047
4	3	3	20.79	26.35709
4	4	4	19.9261	25.98845
			Mean	10.42322

Table 4: Results are MRR and S/N Radio

Source	DF	Seq SS	Adj SS	Variance	F
Current	3	776.68613	776.68613	258.89538	3.71639
Pulse on time	3	27.56851	27.56851	9.18950	0.13191
Pulse off time	3	27.56851	27.56851	9.18950	0.13191
Residual Error	3	208.98967	208.98967	69.66322	1
Total	12	1040.81267			

Table 5: Experimental Results for F-Test in MRR

CURRENT (AMP)	PULSE ON TIME (µS)	PULSE OFF TIME (µS)	OC (mm)	S/N(dB) FOR OC
1	1	1	0.708	2.99933
1	2	2	0.7135	2.93212
1	3	3	0.719	2.86542
1	4	4	0.7245	2.79923
2	1	1	0.7355	2.66834
2	2	2	0.741	2.60363
2	3	3	0.7465	2.53940
2	4	4	0.752	2.47564
3	1	1	0.7575	2.41234
3	2	2	0.763	2.34950
3	3	3	0.7895	2.05295
3	4	4	0.816	1.76619
4	1	1	0.8425	1.48860
4	2	2	0.869	1.21960
4	3	3	0.8955	0.95868
4	4	4	0.922	0.70538
			Mean	2.17728

Table 6: Experimental Results for OC and S/N Radio

Source	DF	Se q SS	Adj SS	Variance	F
Current	3	7.4122	7.4122	2.4707	24.3089
Pulse on time	3	0.4769	0.4769	0.1589	1.5641
Pulse off time	3	0.4769	0.4769	0.1589	1.5641
Residual Error	3	0.3049	0.3049	0.1016	1
Total	12	8.0612			

Table 7: Experimental Results for F-Test in OC

C. S/N Ratio Graph for MRR (Larger the Better):

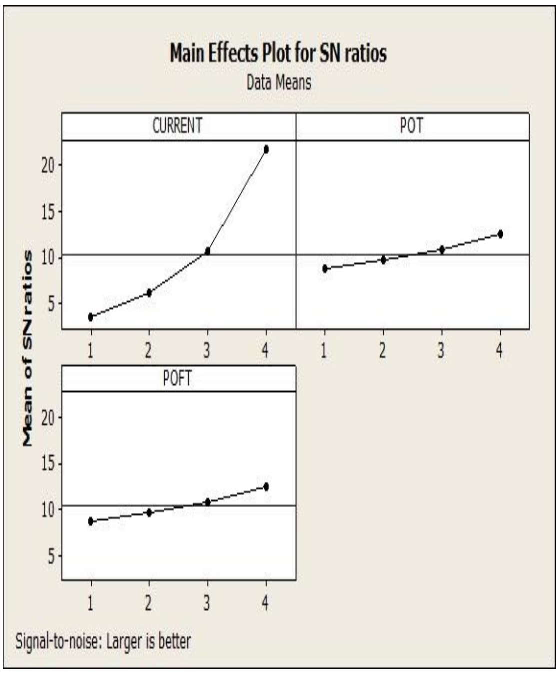

Fig. 1: S/N ratios Graph for MRR

D. Best Machining Condition for Higher MRR:

For the F-test,
Comparing the tabulated and calculated values

- Current is the most significant at 95% confidence level
- Pulse on time and off time are insignificant one

For the above test to find out the best machining condition,

A4 B4 C4 – current=6 amps, pulse on time=80 µs and Pulse off time=90 µs

E. S/N Ratio Graph For Over Cut (Smaller the Better):

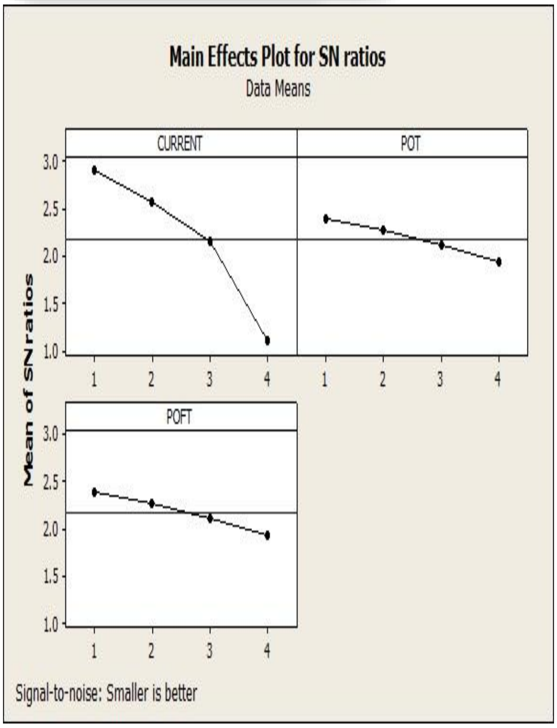

Fig. 2: S/N ratios Graph for over cut

F. Best Machining Condition For Lesser Over Cut:

For the F-test,
Comparing the tabulated values and calculated values

- Current is the most significant at 95% confidence level
- Pulse on time and off time are insignificant one

For the above test to find out the best machining condition,

A1 B1 C1 – Current=2 Amp, Pulse on time=20 µs and Pulse off time=10 µs

IV. CONCLUSION

This work mainly consists of various activities to show the influence of different ascendant process parameters of µEDM on the machining rate and accuracy. The process parameters like current, pulse on time and off time have been considered to analyze the influence on MRR and OC.

The optimal machining condition for getting higher material removal rate in brass is found to be 6 A, 60 µsec (Pulse on time), and 70 µsec (Pulse off time). The optimal machining condition for getting lower over cut in brass is found to be 2 A, 20 µsec (Pulse on time), and 10 µsec (Pulse off time). ANOVA determines the factors which have significant on material removal rate and the optimal setting is found by S/N ratio. Machining current is found to be most significant factor. Pulses on time and off time are found to be insignificant factor.

REFERENCES

[1] Pradhan B B, Masanta M,Sarkar B R and Bhattacharyya B(2009) ‘Investigation of electro-discharge micro-machining of titanium super alloy’ International journal advanced manufacturing technology,Vol.41 pp. 1094-1106

[2] Lingxuan Zhang, Zhenyuan Jia, Fuji Wang and Wei Liu (2010) ‘A hybrid model using supporting vector machine and multi-objective genetic algorithm for processing parameters optimization in micro-EDM’, International journal of advanced manufacturing technology, Vol. 51 No. 5-8 pp. 575-586.

[3] Yan Cherng Lin, Biing Hwa Yan and Yong Song Chang (2000) ‘Machining characteristics of titanium alloy (Ti-6Al-4V) using a combination process of EDM with USM’ Journal of Materials processing technology Vol.104 pp.171-177.

[4] A Cheng Wang ,Biing Yan, Xiang Tai Li and Fuang Yuan Huang (2002) ‘Use of micro ultrasonic vibration lapping to enhance the precision of micro holes drilled by micro electro-discharge machining’ International journal of machine tools and manufacture, vol.42 No. 8 pp. 915-923.

[5] Changshui Geo and zhengxun Lin (2003) ‘A study of ultrasonically aided micro-electrical-discharge machining by the application of work piece vibration’ Journal of materials processing technology, Vol. 139 N0.1-3 pp. 226-228.

[6] Diver C, Atkinson J, Helml H.J and Li L (2004) ‘Micro-EDM drilling of tapered holes for industrial applications’, Journal of materials processing Technology, Vol. 149 No.1-3 pp. 296-303.

[7] Do Kwan Chung, Hong Shik Shin, Min Soo Park and Chong Nam Chu (2011) 'Machining characteristics of micro EDM in water using High Frequency Bipolar Pulse', International Journal of Precision Engineering and Manufacturing, vol. 12 No.2 pp. 195-201.
[8] Fuzhu han, Yuji Yamada, Taichi Kawakami and Masanori Kunieda (2006) 'Experimental attempts of sub-micrometer order size machining using micro-EDM' Precision Engineering, vol. 30 pp. 123-131.
[9] Gunawan setia prihandana, Muallim Mahardika, Hamdi M, Wong Y.S and Kimiyuki Mitsui (2011) 'Accuracy improvement in nanographite powder-suspended dielectric fluid for micro-electrical discharge machining processes', International Journal of Advanced Manufacturing Technology, Vol. 56 No. 1-4 pp.143–149.
[10] Guohui Cao, Wansheng Zhao, Zhenlong Wang and Yongfeng Guo(2005) 'Instantaneous fabrication of tungsten microelectrode based on single electrical discharge', Journal of materials processing Technology, Vol. 168 No.1 pp.83-88.
[11] Gwo-Lianq Chern and Yin Chuang (2006) 'Study on vibration-EDM and mass punching of micro-holes', Journal of materials processing technology, Vol. 180 No.1-3 pp. 151-160.

