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Comparative Study of Taguchi and Genetic Algorithm in Electric Discharge Machining Parameters on Titanium Alloy (Ti 6Al 4V)

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Abstract
The aim of this work is to research the have an effect on of manner parameters and determine the top of the line system parameters in electric discharge machining (EDM) of Titanium alloy (Ti 6Al 4V) .The parameters taken into consideration are peak modern, pulse on time and pulse off time in which as the responses are material removal rate (MRR) and surface Roughness (SR). MITSUBISHI EA8 spark erosion machine is hired for this paintings and copper tungsten electrode of Ø14 mm is utilized in experimental trials. The experimental trials are carried out based totally on Taguchi L27 orthogonal array with 3 levels of every machining parameters. The signal to noise ratio, the evaluation of variance (ANOVA), regression analysis and Genetic algorithm are hired to locate the highest quality stages and to analyze the consequences of machining parameters on metal elimination charge and floor roughness. Confirmation tests with the most beneficial levels of machining parameters are completed which will illustrate the effectiveness of Taguchi and Genetic set of rules optimization approach. Assessment of Taguchi's and Genetic set of rules had been employed to analyze the effective top quality fee.

Keywords: *EDM, Ti–6Al–4V alloy, Peak current, Pulse on time, Taguchi method.*

INTRODUCTION

Ti–6Al–4V alloy is an important fabric in modern industry. Its top notch homes, such as high electricity weight ratio, high temperature balance and brilliant corrosion resistance, make it broadly used in the aerospace, automobile, chemical and biomedical fields. But, the bad machinability of titanium alloys the use of the conventional mechanical reducing manner outcomes in high tooling fees. consequently, non conventional machining techniques, which include electric discharge machining (EDM) were explored to system this alloy.EDM is an energy based technique extensively used in machining hard, high strength and temperature resistant materials in a contactless manner. The material is melted and vaporized by an erosion spark between the electrode and work piece. Kao et al. noted a higher material removal rate (MRR) and lower surface roughness (SR) using distilled water as the dielectric compared to using kerosene [1]. Ponappa et al. attempted to improve the discharge efficiency of magnesium nanoalumina composites using EDM [2]. Anand pandey et al. explored the influence of EDM parameters on the surface integrity with different electrode materials and process [3]. Recently, Velusamy et al. used EDM technology to machine aluminum composites to examine the effect of process parameters [4]. Sharma showed the most efficient parameters are pulse current and pulse duration on the surface integrity of the material among the other EDM parameters [5]. In this work, the optimization of parameters considering multiple performance characteristics of the EDM system to Ti–6Al–4Valloy the usage of the Taguchi method and ANOVA evaluation is reported.Overall performance traits inclusive of material elimination rate and floor Roughness's are chosen to assess the machining consequences. those process parameters that are carefully correlated with the selected regression evaluation performance traits on this study are the height cutting edge, pulse on time and pulse off time.

Experiments

A cylindrical copper tungsten rod 14 mm in diameter and 100 mm in height was used as the electrode in the CNC EDM machine (MITSUBISHI EA8) to erode the work piece of Ti–6Al 4V alloy in this study. The specimen size used in this work is 25×25×5mm.The material properties of the alloy as well as the chemical compositions are shown in Table 1. However, there are several machining parameters to be considered in the EDM process. As a result, a preliminary experiment for determining the optimal process parameters indicates the machining parameters such as peak current, pulse on time and pulse off time have a clear effect on the EDM performance of Ti–6Al–4V alloy.

Table.1.*Material properties of Ti–6Al–4V alloy and its chemical composition*

Work piece	Ti 6Al 4V
Hardness (HRC)	36~39
Solidus temperature (°C)	1,604±11
Liquides temperature (°C)	1,660±14
Density (g/cm^3)	4.043
Elastic modulus (kg/mm^2)	11,200
Yield strength (kg/mm^2)	84.2
Tensile strength (kg/mm^2)	91.3
Elongation (%)	10
Electrical resistivity (μΩ·m)	1.7

Ti=89.464, Al=6.08, V=4.02, Fe=0.22, O=0.18, C=0.02, N=0.01, H=0.0053

Table .2 .*Machining parameter*

SL	Parameters	L2	L2	L3
A	Peakcurrent, (A)	9.0	9.0	14
B	Pulseon time (μs)	12.8	12.8	25.6
C	Pulseoff time (μs)	25.6	25.6	51.2

The various parameters and its levels are shown in Table 2.This experiment used a negative polarity electrode and DAPHANE CUT –HL35 was used as the dielectric fluid in all experiments. The experimental setup shown in the fig.1.The experiments are conducted based on L27 Taguchi orthogonal array. The fixed experimental parameters used in this study are shown in Table 3. This work also used MATLAB 7.4 to optimize the surface roughness and material removal rate using Genetic Algorithms. Each experiment was repeated two times and the average of values taken is for determining optimal parameters. The MRR and SR of the machined surface are the performance characteristics to evaluate the machining quality. The MRR (mg/min) is defined by the weight of the work piece worn in the period of working time in minute. To measure the weight of the worn work piece removal, Sartorius Mechatronics (Model:BSA 224) was used. In the experiments, the surface roughness of the EDMed work piece in terms of the commonly used Ra (arithmetic average roughness) was measured by a surface roughness tester (Mitutoyo, Surftest SJ201). Basically, the MRR is the category of higher the better performance characteristic in the Taguchi method and SR is the lower the better in the EDM process.

Fig.1. *Experimental set up*

Table .3.Fixed parameter

Work piece	Ti–6Al–4V
Electrode	Copper tungsten
Dielectric fluid	DAPHANECUT–HL35
Polarity	Negative (+)
Machining depth	0.2 mm

Taguchi's Method

Taguchi's method is a well accepted methodology for experiment design. In this, signal to noise ratio(S/N) is used to represent a response or quality characteristics and the largest S/N ratio is required. There are three types of quality characteristics viz. nominal the better, larger the better and smaller the better. In this work, experimentally observed MRR value is "larger the better" and SR are "lower the better". Based on Taguchi's method, the S/N ratio calculated is as shown in below.

i) Larger the better

$$\text{HB}: \quad \eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} yi^{-2}\right] \quad \text{.... [1]}$$

ii) Smaller the better

$$\text{LB}: \quad \eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} yi^{2}\right] \quad \text{[2]}$$

Where *yi* is the experimentally observed value and *n* is the repeated number of each experiment.

Analysis of Variance (ANOVA)

ANOVA is a mathematical technique which breaks total variation down into accountable sources. Some of the components in ANOVA are discussed below.

Sum of squares

The magnitude of each error value can be squared to provide a measurement of total variation present. This is known as "Sum of Squares". The basic ANOVA is that the total sum of squares is equal to the sum of sum of the squares due to known components as shown in Eq. 3.

SST = SSm + SSe …………. [3]

Where,

SST Total sum of squares.

SSm sum of squares due to mean.

SSe sum of squares due to error.

Variance due to error

Experiments based on L27 orthogonal array are conducted. Optimized method parameters concurrently main to higher cloth removal fee and higher floor roughness is then be tested through a confirmation experiment. The information of the strategies are addressed inside the following sections.

F test for comparison

The F test is simply a ratio of sample variances as shown in Eq. 4.

$F = Sy1^2/Sy2^2$……………. [4]

4.4. Percent contribution

The percent contribution indicates the relative power of a factor and/or interactions to reduce variation.

Genetic Algorithm

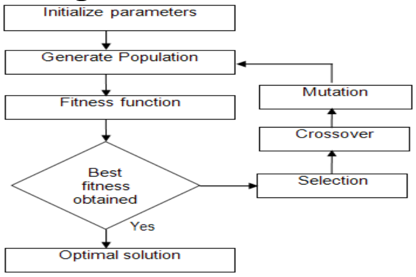


Fig.2. *Flow of Optimization in GA*

The goal of the optimization technique the use of Genetic set of rules is to decide the most efficient values of choice variables that contribute to the minimal value of surface roughness being as little as possible. There can be a complete of four optimization troubles to be solved. Each optimization trouble includes a minimization characteristic described with the aid of one of the 2nd order equations. Obtaining outcomes in Genetic set of rules (GA) is based on some criteria. As proven in fig 2. The most important parameters to be considered are population size, the type of selection function, the crossover rate and the mutation rate. By the process of trial and error the value or parameter setting for these criteria is made for obtaining the most optimal result that is expected from this study. The Mat lab optimization toolbox is used in the study for performing iterations in order to present the best optimal results. The best combination of these values for cutting conditions will lead to the minimum surface roughness. Number of trials was conducted with different value settings for the cutting conditions for searching the minimization values of surface roughness using the Mat lab optimization toolbox, the best combination of the parameters applied.

Results and Discussions

Regression analysis

The peak current, pulse on time and pulse off time were considered in the development of regression equation for the material removal rate and surface roughness. A linear polynomial model is developed to predict the material removal rate and surface roughness value for each experimental trail as listed in Table .4.
The regression equation for material removal rate and surface roughness is shown in below

MRR = 1.84 + 0.428 Peak current + 0.0777 Pulse on time + 0.0004 Pulse off time……………………………….. [5]

SR = 3.25 + 0.0724 Peak current + 0.0225 Pulse on time 0.0215 Pulse off time……………. [6]

6.2. Material removal rate

Material removal rate is expressed as the ratio of the difference of weight of the work piece before and after the machining to the machining time.
MRR= (wjb − wja)/t (mg/min)…[7]
Where, wjb and wja are weights of work piece before and after the machining and t is the machining time.
The machinability of EDM depends on the electrical conductivity of the work material. Despite the low electrical conductivity and high thermal resistance of the material, which ultimately reduces the electrical conductivity of the work material, the results obtained indicate that Titanium alloy can be machined effectively using EDM. MRR was found to increase with increase in current and pulse on time. It is also evident that the surface roughness value increases with increase in current and pulse on time. High current results in higher thermal loading on both

electrodes (tool and work piece) followed by higher amount of material being removed from both electrodes and hence lead to high MRR and TWR as well. Furthermore, longer pulse duration also results in a large removal per discharge, which results in larger crater size and therefore higher surface roughness. The S/N response graph in Fig. 3 shows the material removal rate increases with an increase in the current. For the performance characteristic of the material removal rate, the peak current level 3 ,pulse on time level 3 and pulse off time level 1 parameters including a current of 14A, pulse on time 25.6µs and pulse off time 12.8 µs as shown in Fig.3 can lead to optimal result. Optimum value is getting from the response table is shown. ANOVA results are shown in Table 5. Observation of this table discharge current is the most dominant factor having percentage of contribution as 62.74% , followed by pulse on time 22.53% and pulse off time 5.18% are affect the material removal rate and the interaction factors are not contributing most significantly.

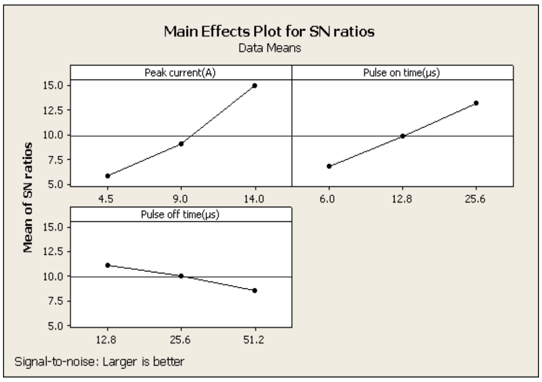


Fig .3.*S/N ratio graph for MR*

Surface Roughness
It was observed that pulse off time has a considerable effect on surface roughness. When the pulse off time is increased the machining action also not take place on the work piece that the time the dielectric fluid is forced into the spark gap, short circuiting becomes less pronounced as a result of the accumulated particles. Higher pulse off time removes the formation of ionized bridges across the gap and results in higher ignition and decreased surface roughness. Further, the cooling rate of the tool increases with increase in the pulse off time and hence improved surface Roughness is observed.

It is found that the discharge current has a leading effect on surface roughness. The S/N response graph in Fig. 4 shows the surface roughness decreases upon decreasing the discharge current. It indicates that a better surface quality can be obtained under a lower discharge current with shorter pulse duration owing to the lower power erosion process. Figure 4 shows when only the performance characteristic of the surface roughness is considered, a parameters set peak current level 1,pulse on time level 2 and pulse off time level 3 with a current of 4.5 A, pulse on time 12.8µs and pulse off time 51.2µs can result in an optimal outcome. Optimum values are getting from the response table. ANOVA table is shown in table 6. From this table pulse off time is most significantly contribution is 20.78%, peak current is 9.49%,pulse on time is 8.69%, interaction terms significantly contribution is AB,BC and AC as 12.06%, 20.78% and 19.49% respectively. The electric discharge machined surface consists of a multitude of overlapping craters that are formed by spark discharges.

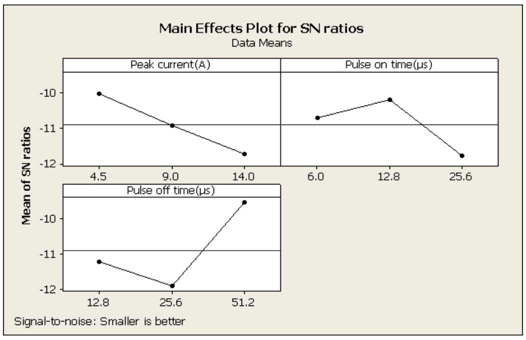


Fig .4.*S/N ratio graph for SR*

Determination of surface roughness using GA

The optimum selection of machining parameters should increase not only the utility of machining economics, but also the product quality to a great extent by minimizing surface roughness value. The process parameters of EDM are defined in the standard optimization format that is solved by a numerical optimization algorithm. An objective function to be minimized is necessary to define the standard optimization problem. In EDM machining of titanium alloy, optimization problem can be expressed as

Minimize: a(IP,Ton,Toff)

Within range of machining parameters:

4.5 A <IP< 1 4 A

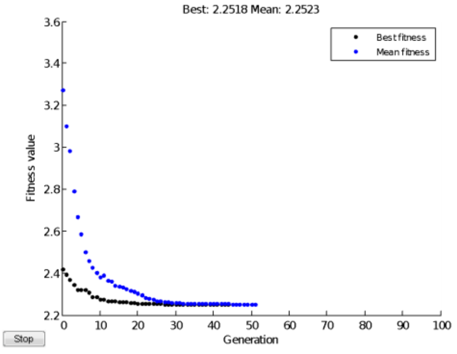
6 µs <Ton< 25.69 µs

12.8 µs <Toff< 51.2 µs

Table .4.*Experimental results for the MRR and SR*

Sl.No	IP (A)	Ton (µs)	Toff (µs)	Avg.SR(µm)	Predicted SR(µm)	S/N ratio for SR	Avg.MRR (mg/min)	Predicted MRR	S/N for MRR
1	4.5	6.0	12.8	2.73	3.2470	8.7233	1.013	1.3377	0.1122
2	4.5	6.0	25.6	3.21	3.1604	10.1301	1.121	0.9844	0.9921
3	4.5	6.0	51.2	2.32	2.6100	7.3098	1.596	1.1190	4.0607
4	4.5	12.8	12.8	3.42	3.5886	10.6805	2.345	2.1060	7.4029
5	4.5	12.8	25.6	3.89	3.3134	11.7990	2.106	1.7528	6.4692
6	4.5	12.8	51.2	2.28	2.7630	7.1587	1.987	1.0462	5.9640
7	4.5	25.6	12.8	3.12	3.8766	9.8831	3.675	3.5525	11.3051
8	4.5	25.6	25.6	4.62	4.3221	13.2928	2.975	3.1992	9.4697
9	4.5	25.6	51.2	3.67	3.3360	11.2933	2.022	2.4926	6.1156
10	9.0	6.0	12.8	4.37	4.3650	12.8096	2.789	3.0837	8.9090
11	9.0	6.0	25.6	3.94	3.4862	11.9099	1.778	2.3254	4.9986
12	9.0	6.0	51.2	2.47	2.9358	7.8539	1.142	1.8850	1.1533
13	9.0	12.8	12.8	2.58	2.8659	8.2324	3.345	3.8521	10.4879
14	9.0	12.8	25.6	3.65	3.6392	11.2459	2.250	2.9861	7.0437
15	9.0	12.8	51.2	3.07	3.0888	9.7428	2.221	2.7923	6.9310
16	9.0	25.6	12.8	3.43	3.5542	10.7059	5.879	5.2985	15.3861
17	9.0	25.6	25.6	5.87	5.5986	15.3728	4.987	4.9452	13.9568
18	9.0	25.6	51.2	3.33	3.3768	10.4489	4.107	4.2387	12.2705
19	14.0	6.0	12.8	6.33	6.0123	16.0281	4.565	5.0237	13.1888
20	14.0	6.0	25.6	3.52	3.8482	10.9309	6.680	5.983	16.4955
21	14.0	6.0	51.2	3.44	3.2978	10.7312	3.486	3.9639	10.8465
22	14.0	12.8	12.8	4.23	4.2764	12.5268	6.333	5.7921	16.0322
23	14.0	12.8	25.6	3.24	4.0012	10.2109	5.321	5.4388	14.5199
24	14.0	12.8	51.2	3.22	3.4508	10.1571	4.935	4.7323	13.8657
25	14.0	25.6	12.8	3.75	4.4587	11.4806	7.332	7.2385	17.3044
26	14.0	25.6	25.6	4.10	4.2892	12.2557	6.890	6.8852	16.7644
27	14.0	25.6	51.2	3.64	3.7388	11.2220	6.233	6.1787	15.8939

MATLAB 7.4 is used to optimize the surface roughness using Genetic Algorithms. The critical parameters of the GA are the size of the population, cross over rate and mutation rate.



*Fi.5.**Genetic Algorithm fitness graph for SR***

Population size = 100
Crossover rate = 0.95
Mutation rate = 0.41

Determination of Material removal rate

An objective function to be maximized is necessary to define the standard optimization problem. In EDM machining of titanium alloy, optimization problem can be expressed as

Maximize: MRR (IP, Ton, T_{off})

Within range of machining parameters:

***Table.5.**ANOVA results for the MRR*

Source	DF	SS	MS	Fcal	Ftab	Inferen	% Contribu
A	2	63.69	31.84	76.6	4.46	Sig	62.74
B	2	22.86	11.44	27.5	4.46	Sig	22.53
C	2	5.25	2.62	6.33	4.46	Sig	5.18
AB	4	2.61	0.65	1.58	3.84	In Sig	2.58
BC	4	1.65	0.41	1.00	3.84	In Sig	1.63
AC	4	2.10	0.52	1.27	3.84	In Sig	2.08
Erro	8	3.31	0.41				3.26
Total	26	101.5					100

***Table.6.**ANOVA results for SR*

Source	DF	SS	MS	F ca	F t	Inference	% of Contributio
A	2	2.15	1.07	3.	4	Insig	9.49
B	2	1.97	0.98	3.	4	Insig	8.69
C	2	4.47	2.23	8.	4	Signif	20.78
AB	4	2.73	0.68	2.	3	Insig	12.06
BC	4	4.71	1.17	4.	3	Signif	19.73
AC	4	4.41	1.10	3.	3	Signif	19.49
Erro	8	2.21	0.27				9.76
Total	2	22.6					100

A Peak current (A), B Pulse on time (µs), C Pulse off time (µs), AB Peak current* Pulse on time, BC Pulse on time * Pulse off time, AC Peak current* Pulse off time, DF degree of freedom, SS sum of square, F cal F Calculated value, F tab F value from tab .

4.5 A <IP< 1 4 A
12.8 µs <Toff< 51.2 µs
6 µs <Ton< 25.69 µs

MATLAB 7.4 is used to optimize the material removal rate using Genetic Algorithms. The critical parameters of the GA are the size of the population, cross over rate and mutation rate.

Population size = 50
Crossover rate = 0.70
Mutation rate = 0.63

The Genetic Algorithm based optimization approach provides a sufficient approximation to the true optimal solution. Tables 7 and table 8 shows the extreme of optimization function with relevant machining conditions.

CONFIRMATION TESTS

Since the optimal EDM process parameter set is obtained, the confirmation tests are processed to verify the performance characteristics improvement. Confirmation result is shown in table 7and table 8.

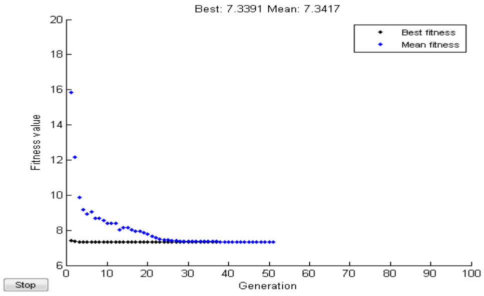


***Fig .6.**Genetic Algorithm fitness graph for MRR*

The experimental response variable using the optimal machining parameters can be found out even for the setting not available in the OA.

***Table .7.**EDM performance results using the initial, Prediction and GA process parameters for MRR*

Parameter/ Optimized Methods	**A (A)**	**B (µs)**	**C (µs)**	**MRR (mm^3 /min)**
Taguchi (A3B3C1)	14	25.6	12.8	7.332
Prdiction (A3B3C1)	14	25.6	12.8	7.2385
Genetic Algorithm	4.5	6	14.925	7.3391
Confirmation (A3B3C1)	14	25.6	12.8	7.36

***Table .8.**EDM performance results using the initial, prediction and GA process parameters for SA*

Parameter/optimized methods	**A (A)**	**B (µs)**	**C (µs)**	**SR (µm)**
Taguchi (A1B2C3)	4.5	12.8	51.2	2.28
Prediction (A1B2C3)	4.5	12.8	51.2	2.763
Genetic Algorithm	4.50	6.0071	51.1985	2.251
Confirmation (A1B2C3)	4.5	12.8	51.2	2.27

The results of confirmation experiment are compared with the outcome of the orthogonal array and regression analysis prediction of the equation operating parameters. Table 7 and table 8 shows the comparison of the experimental results using the initial (orthogonal array, A3B3C1),optimal (regression prediction, A3B3C1) and Genetic algorithm EDM parameters on Ti–6Al–4V alloy. Table 7 and table 8 shows the MRR increased from 7.238 to 7.360 mg/min and the surface roughness decreased from 2.76 to 1.78µm respectively. The corresponding improvement in MRR is 2% and surface roughness 17.75%, respectively.

Conclusion

An application of the Taguchi method and ANOVA analysis to improve the multiple performance characteristics of the material removal rate and surface roughness in the electrical discharge machining of Ti–6Al–4V alloy has been reported in this paper. This work shows optimization of the machining parameters in the EDM machining of Ti–6Al–4V alloy using Taguchi method. The most significantly contributing factors are identified by using ANOVA. In this experiment MRR increases with an increase in the peak current and as well as pulse on time.SR improves increases with an increase in pulse on time. The optimum machining conditions for material removal rate with the peak current of 14A, pulse on time 51.2µs and pulse off time 12.8µs.In this optimum MRR is 7.332 mg/min. The optimum machining conditions for surface roughness with the peak current of 4.5A, pulse on time 12.8µs and pulse off time 51.2µs.The corresponding SR is 2.28µm.The optimum conditions for the two response functions are different. Genetic Algorithm were giving the optimum combination of parameters for the material removal rate is with the peak current of 4.5A, pulse on time 6µs and pulse off time 14.9254µs.In this optimum Material removal rate is 7.3391 mg/min. The optimum combination of parameters for the surface roughness is with the peak current of 4.50052A, pulse on time 6.00718µs and pulse off time 51.19852µs.The corresponding optimum Surface roughness is 2.2518µm.

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