GREY RELATIONAL ANALYSIS PROCESS PARAMETER OPTIMIZATION FOR ELECTRICAL DISCHARGE MACHINING OF TITANIUM ALLOY

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ABSTRACT

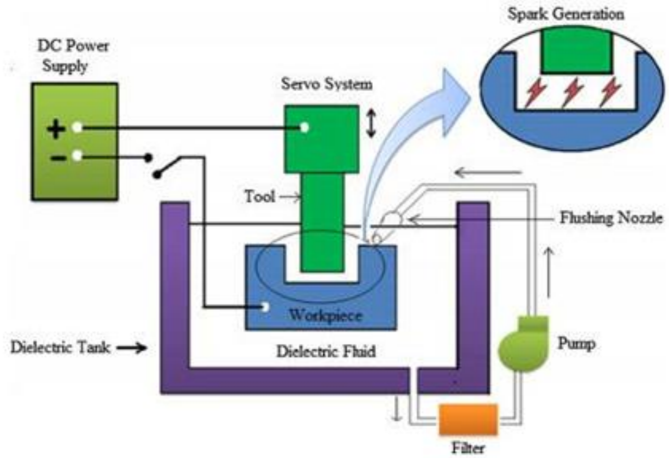
Ti-6Al-4V is one of the titanium alloys that is often used in a variety of industrial applications. This material is challenging to work with using standard machining techniques. In this study, an innovative machining technique called electrical discharge machining was used to machine Ti-6Al-4V. (EDM). Grey Relational Analysis was used to examine how multi-objective optimization of input EDM parameters affected the responses of Ti-6Al-4V by the EDM process. These process parameters: current (Io), pulse on time (tonne), and gap () were chosen. Metal Removal Rate (MRR) and Electrode Wear Rate were the selected replies (EWR). The tests were carried out using the Taguchi L9 orthogonal array with the three levels and three specified process parameters. The use of the grey relation grade identifies the EDM input parameter levels that are optimal. The optimum levels of parameters obtained using grey relational grade were current at level 1, pulse on time at level 1 and gap at level 3 out of the three levels chosen.

Keywords: EDM, optimization, process parameters, Grey relational analysis

INTRODUCTION

Ti-6Al-4V's remarkable metallurgical and mechanical qualities have significantly boosted demand in recent years [1]. The mach inability of this alloy when cut using normal machining techniques is low, especially when producing micromoles [2]. EDM is a relatively new method of cutting Ti alloys that has several advantages over previous methods [3]. It is typically used for cutting tough-to-machine materials and alloys with high strength and temperature resistance [4]. Some of the process parameters in the EDM process include peak current, pulse on time, dielectric pressure, tool diameter, discharge current, voltage, dielectric, machining time, and polarity [5,6]. Thermal energy is used in this technique to remove the substance [7]. In this non-traditional process, electrical energy is used to produce the electrical spark. Thermal energy of the spark is responsible for material removal rate in EDM. The temperature at the spark zone is actually high enough to vaporize the material. Schematic diagram of experimental set-up for EDM process is shown in figure 1. Although EDM is vital in getting different shapes of structural components, it needs an improvement in machining efficiency [8].

Fig.1: Schematic diagram of experimental set-up for EDM [9]



Experimentation and Analysis

Experimentation

Electronica V- 425 EDM machine as shown in figure 2 was used to carry out the experiments.Ti-6Al-4V was the target material and copper was used as tool with a diameter of 6 mm.

Fig.2: Electrical Discharge Machine

Three process parameters namely Current, Pulse on time and Gap were selected with three levels. Using Taguchi L9 array experiments were performed. Each experiment was performed thrice to get the accurate values of responses. The responses selected were Metal Removal Rate and Electrode Wear Rate. Table 1 shows the process parameters and their levels.

Table 1: Process parameters and their levels

Control parameter	**Level**			**Responses**
	L1	**L2**	**L3**	
I_o (A)	6	12	18	
t_{on} (µs)	30	60	90	MRR
δ (mm)	10	12	18	EWR

Experimental Results for EWR and MRR are shown in Table 2.

Table 2: Experimental Results for EWR and MRR

Expt. No.	I_o (A)	t_{on} (μs)	δ (mm)	EWR (%)			MRR (mg/min)		
				T1	T2	T3	T1	T2	T3
1	6	30	10	7.148	7.139	7.131	2.604	2.632	5.155
2	6	60	12	7.162	7.157	7.156	2.517	2.517	1.669
3	6	90	18	7.130	7.127	7.127	6.040	9.033	6.977
4	12	30	12	7.109	7.103	7.107	3.472	3.534	3.497
5	12	60	18	6.994	6.985	6.975	8.333	8.130	8.000
6	12	90	10	7.108	7.103	7.090	4.167	4.065	24.000
7	18	30	18	7.08	7.087	70.078	16.000	15.600	11.600
8	18	60	10	7.058	7.094	7.015	1.838	1.859	1.855
9	18	90	12	7.013	7.010	7.002	3.670	3.704	5.455

Multi-response optimization using grey relational analysis

S/N ratios were calculated for EWR and MRR and are tabulated below in Table 3.

Table 3: S/N ratios for EWR and MRR

S. No	S/N Ratio	
	EWR	MRR
1	-17.073	9.593
2	-17.096	6.482
3	-17.059	16.974
4	-17.033	10.883
5	-16.883	18.224
6	-17.025	13.985
7	-17.006	22.883
8	-16.971	5.346
9	-16.912	12.200
Min	-17.096	5.346
Max	-16.883	22.883

The Combination of Grey relational analysis and Taguchi method is known as Taguchi Grey relation analysis [10]. The following are the sequence of steps followed in multi response optimization.

Step 1

The initial step in the Grey relational analysis is to normalize the experimental data [11]. The normalization data will be in the range of 0 and 1. The normalization process depends on the performance response. The responses in this work namely MRR and EWR are to be normalized with larger-the-better and smaller-the-better characteristic respectively and shown below. Table 4 shows the normalization values of responses using tabulated S/N ratios.

The following is the equation for normalization to maximize the response for “Larger the better” criteria [11].

$$x_i^*(k) = \frac{x_i^0(k) - \min x_i^0(k)}{\max x_i^0(k) - \min x_i^0(k)}$$

where x_i*(K) is the normalized value and x_i^0(K) is the response value, min x_i^0(K) is the lowest response value and max x_i^0(K) is the highest response value.

The following is the equation for normalization to minimize the response for “Smaller the better” criteria [12].

$$x_i^*(k) = \frac{\max(x_i^0(k)) - x_i^0(k)}{\max(x_i^0(k)) - \min(x_i^0(k))}$$

Where x_i*(K) is the value after grey relational generation (normalized value), max(x_i^0(K)) and min(x_i^0(K)) are the largest and smallest values of x_i^0(K) for the k^{th} response.

Table 4: Normalized values of EWR and MRR

Normalization	
EWR	**MRR**
0.892	0.242
1.000	0.065
0.826	0.663
0.702	0.316
0.000	0.734
0.667	0.493
0.576	1.000
0.411	0.000
0.137	0.391

Step 2

A grey relation coefficient was calculated by the following equation

where Δ_{oi}(k) is the deviation sequence, the difference of the reference sequence x_0*(k)and comparability sequence x_i*(k). is distinguishing or identification coefficient and is assumed to be 0.5 since all the parameters are given equal preference. Δ_{max} is the highest value of Δ_{oi}(k); Δ_{min} is the lowest value of Δ_{oi}(k) . Δ_{oi} values and Grey relation coefficients of the present work are tabulated in Tables 5 and 6 respectively. Here Δ_{max} is 1 and Δ_{min} is 0.

Step 3

Grey relational grades are calculated by doing the average the GRC corresponding to each performance characteristic as shown below.GRG values are tabulated in Table 7 and ranks are shown in Table 8.

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k)$$

Table 5: Grey relation

Grades

Exp. No	**Grade (γ)**
1	0.610
2	0.674
3	0.670
4	0.524
5	0.493
6	0.548
7	0.771
8	0.396
9	0.409

Rank 1 is obtained for the experiment number 7 since order of rank 1 will be given to highest grey relational grade and indicated in table 2. Therefore experiment number 7 will have initial parameter setting for obtaining maximum metal removal rate and minimum electrode ware rate among the nine chosen experiments. So the initial optimal parameter setting was I_o 3, t_{on} 1 and δ3.

Step 4

Response table for signal to noise ratios and response table for means of GRG was shown in Tables 6 and 7 respectively.

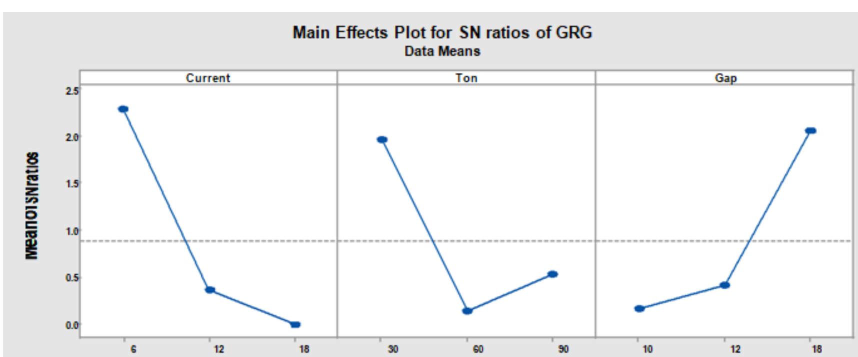
Table 6: Response table for signal to noise ratios

Level	I_o	t_{on}	δ
1	-3.734	-4.057	-5.852
2	-5.656	-5.868	-5.601
3	-6.024	-5.489	-3.961
Delta	2.290	1.812	1.891
Rank	**1**	**3**	**2**

Table 7: Response table for Means

Level	I_o	t_{on}	δ
1	0.6513	0.6349	0.5181
2	0.5219	0.5212	0.5357
3	0.5252	0.5423	0.6446
Delta	0.1293	0.1137	0.1264
Rank	**1**	**3**	**2**

Fig.3: Main Effects Plot for SN ratios of GRG



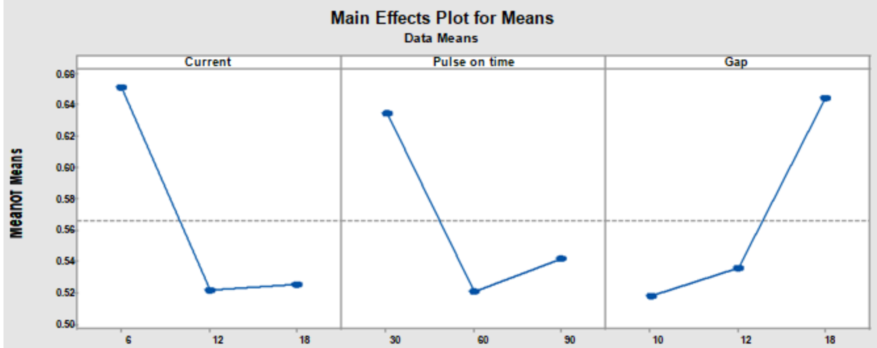


Fig.4: Main Effects Plot for means of GRG

Now from the above Table 7 i.e., response table for means select the level that belongs the highest values for a particular parameter as shown in Table 8.

Table 8: Optimum parameters

	I_o	t_{on}	δ
Level	1	1	3
Value	0.6513	0.6349	0.6446

The above table helps in setting the optimal parameters as current at level 1, pulse on time at level 1 and gap at level3. Main effects plots for S/N ratios and means are shown in figures 3 and 4 respectively.

Table 9: ANOVA analysis

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value
I_o	2	25.65 %	0.097841	0.048921	7.33	0.004
t_{on}	2	17.24%	0.065777	0.032889	4.93	0.018
δ	2	22.13%	0.084417	0. 042208	6.32	0.007
Error	20	34.99%	0.133476	0. 006674		
Total	26	100%				

From the above table it is clear that the order of significant parameters affecting the responses are in the order of current whose P-value is 0.004, Gap whose P-value is 0.007 and pulse on time whose P-value is 0.018 and are verified with Table 9. After the optimal parameter setting is done experiment was carried out since this combination of parameters which was shown in Table 11 was not found in Table 2. Through the conformation experiment the values of the responses at this optimal parameter setting was found out.

Conclusions

This paper has presented Taguchi Grey Relational Analysis for the EDM process of Ti-6Al-4V. Grey relational analysis has been carried out for studying the optimization of EDM process parameters for Ti-6Al-4V. Grey relational grade is used in determining the optimum process parameters for multiple performance characteristics namely MRR and EWR. Taguchi L9 array was used to conduct the experiments. The following conclusions can be drawn from this analysis.

1. Current, Pulse on time, Gap were the selected process parameters.
2. Metal removal rate and Electrode wear rate were the considered responses.
3. Multi response optimization was carried using Grey relational analysis.
4. Normalization of experimental data was carried out using "Larger the better" case for Metal removal rate and " Lower the better" case for Electrode wear rate.

References

[1] J. Prasanna , L. Karunamoorthy, M. Venkat Raman, Sai Prashanth, D. Raj Chordia, "Optimization of process parameters of small hole dry drilling in Ti–6Al–4V using Taguchi and grey relational analysis", Measurement, Volume 48, February 2014, Pages 346-354.

[2] V. Krishnaraj, "Optimization of Process Parameters in Micro-EDM of Ti-6Al-4V Alloy", Journal of Manufacturing Science and Production, 2016, pp.1-9

[3] M. M. Rahman, "Optimization of Process Parameters on Ti-6Al-4V Using Central Composite Design Method", Advanced Materials Research Vols. 189-193 (2011) pp . 1393-1400.

[4] Narinder Singh, Onkar Singh Bhatia, "Analysis of the Influence of EDM Parameters on Material Removal Rate of Low Alloy Steel and Electrode Wear of Copper Electrode", International Journal of Advanced Research in Science, Engineering and Technology, Vol. 3, Issue 6 , June 2016, pp.2322-2330.

[5] P. Balasubramaniana , T. Senthilvelan, "Optimization of Machining Parameters in EDM process using Cast and Sintered Copper Electrodes", Procedia Materials Science, Volume 6, 2014, Pages 1292-1302.

[6] Om Prakash Sahani , Rajneesh Kumar, Meghanshu Vashista, "Effect of Electro Discharge Machining Process Parameters on Material Removal Rate", Journal of Basic and Applied Engineering Research, Volume 1, Number 2; October, 2014 pp. 17-20.

[7] Binayaka Nahak , Ankur Gupta, "A review on optimization of machining performances and recent developments in electro discharge machining", Manufacturing Review, 6, 2 (2019), pp.1-22.

[8] P.Sengottuvel, V.Palanisamy, J.Arun , N.R.R.Anbusagar, J.HameedHussain, "EDM Process Parameters Optimization Using Taguchi Method", Applied Mechanics and Materials Vols. 766-767 (2015) pp 867-872.

[9] Gangaram Mandaloi, Subhash Singh, Pradeep Kumar, Kaushik Pal, "Effect on crystalline structure of AISI M2 steel using tungsten–thorium electrode through MRR, EWR, and surface finish", Measurement · April 2016, pp. 74-84.

[10] Galang Sandy Prayogo, Nuraini Lusi, "Application of Taguchi Technique Coupled with Grey Relational Analysis for Multiple Performance Characteristics Optimization of EDM Parameters on ST 42 Steel", AIP Conference Proceedings 1725, 020061 (2016), pp.1-7

[11] P. Jayaraman, L. Mahesh Kumar, "Multi-response Optimization of Machining Parameters of Turning AISI 6061 T6 Aluminium Alloy Using Grey Relational Analysis In Taguchi Method", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 8 (2015), pp. 6078-6083.