Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

Optimization of EDM process parametrs on hard Ti alloys by using of Grey Taguchi technique

J.Ashok babau[1], Y.Rameswara Reddy[2]

[1]*Mechanical Engineering, JNTUCEP.*
[2] *Mechanical Engineering,JNTUCEP.*

Abstract:*In present industrial world modern machining process performs crucial role for economic development of the country. EDM is one of such unconventional machining process to achieve products with high dimensional accuracy, complicated shape and good quality. EDM is one where electrical sparks are generated by creating voltage difference between the electrode and stationary work piece in dielectric fluid. The material removal takes place due to thermal electric energy of the sparks which melts, evaporates and erodes the work material. EDM is used to machine super hard materials which are not possible to machine in traditional machining processes. The main objective of the present work is to optimize the process parameters to achieve high MRR and low surface roughness. The experiments are conducted on Titanium Alloys Grade-2 and Grade-5 and the tool materials are copper, tungsten copper and graphite of each cross sectional area 10X10mm2 and 70mm of length. Considering process parameters like pulse on time, duty cycle and discharge current. The output process parameters like MRR and SR are determined for every experimental runs. Taguchi L27 orthogonal array design is used to experimental design by Minitab17 software. Finally the multi-objective optimization problem is solved by using Taguchi Grey Relational Analysis.*

Key words: *EDM, Ti Alloys Grade-2 and Greade-5, Tungsten copper, Orthogonal Array, Taguchi Grey Relational Analysis, MRR and SR.*

I. INTRODUCTION

EDM is one of the non-traditional manufacturing process used for removal of metal by an electrical spark erosion process. In these, processes electrical spark is used as a tool to remove material from work piece to produce the finished part to the desired shape. The EDM process uses two electrodes such as tool and the work piece both are separated by dielectric fluid. By the metal erosion process, the top surface of the work piece is subsequently re solidified and cools at a high speed manner. The applications of these EDM process mostly used in dies and press tools, plastic moulds, forging dies, aerospace, automotive and in several engineering applications. Zaheed A. Khan et.al studied the effect of three values of input namely pulse charge(amp), duration of pulse and no pulse time on smoothness of surface in WEDM for machining stainless steel(ss-304).Here L9 based array was selected and total 9 runs of experiments were done. By grey relational grade influence of input on output was found. The ANOVA test revealed that on pulse time was the important factor for minimization both output parameters and as charge increases smoothness is less.V. Muthukumar et.al optimized the Radial overcut (ROC) of Incoloy 800 using copper tool by Response Surface process in die sinking EDM. Totally 30 runs of experiments planned according to CCD (Central composite design) were performed to determine influence of charge, on time pulse, off time pulse and the voltage on ROC. From the ANOVA results they determined that charge and voltage had more effect on ROC and the estimated data matched experimental data with coefficient of determination as 0.9699 of ROC.

II. EXPERIMENTATION

a) MATERIAL SELECTION

Two different types of work pieces are used to do this experiment (i.e. Titanium grade2 and grade5). Three different types of tool materials copper (Cu), Tungsten copper (WCu), Graphite were used to machining the work material. Chemical compositions of the two work pieces are as follows. Below table shows the chemical composition of Titanium grade2 and grade5steels.

Table1. Chemical composition of Titanium grade2 material

Element	Ti	Ni	Mo
Content%	98.49	0.78	0.23

Table2. Chemical composition of Titanium grade5 material

Element	Ti	Al	V	Fe
Content%	89.46	6.01	4.06	0.24

b) *EXPERIMENTAL SETUP*

ELECTRONICA SE-35 type EDM machine was used to conduct the experimentsis shown in fig1.and table3 represents specifications of the machine.

Figure1. Electronica SE35 EDM machine

Table3. Specifications of a Electronica SE 35

Manufacturer and model	Electronica SE-35
Axes	X-500mm, Y-300mm
Operation voltage	115/230 V
Supply voltage fluctuation	Not to exceed ± of the operating voltage
Maximum power consumption	20W
Operating temperature	32-113F
Tool holder capacity	Dia 30mm max
Servo head movement	70mm(min) 300mm (max)

To complete the machining experiment three levels of input parameters are considered and shown in below table4.

Table4. Working conditions

Symbol	Factors	Level 1	Level 2	Level 3
X1	Current	6	8	10
X2	T on	100	150	200
X3	τ	10	11	12
X4	Tool material	Copper	WCu	Graphite

DESIGN OF EXPERIMENTS

L27 Orthogonal Array (OA) DOE is used to do the machining on work pieces. In the present experimental study, discharge Current, Pulse on Time, Duty cycle and tool material has been considered as process variables.

Table5. L27 OA table of experiments

S.NO	I(amp)	Ton (µs)	Duty cycle	Tool material
1	6	100	10	Copper
2	6	100	11	WCu
3	6	100	12	Graphite
4	6	150	10	WCu
5	6	150	11	Graphite
6	6	150	12	Copper
7	6	200	10	Graphite
8	6	200	11	Copper
9	6	200	12	WCu
10	8	100	10	Copper
11	8	100	11	WCu
12	8	100	12	Graphite
13	8	150	10	WCu
14	8	150	11	Graphite
15	8	150	12	Copper
16	8	200	10	Graphite
17	8	200	11	Copper
18	8	200	12	WCu
19	10	100	10	Copper
20	10	100	11	WCu
21	10	100	12	Graphite
22	10	150	10	WCu
23	10	150	11	Graphite
24	10	150	12	Copper
25	10	200	10	Graphite
26	10	200	11	Copper
27	10	200	12	WCu

c) CALUCULATION OF MRR AND SR

The ratio of weight loss of work piece without and with machining to machining time is MRR.MRR is calculated by using of below mentioned formula

$$MRR = \left(\frac{(Weight\ of\ work\ piece\ before\ machining - Weight\ of\ wotk\ piece\ after\ machining)}{machining\ time}\right)$$

SR is measured by using of Mitutoyo Talysurf instrument. In this experimental process, Surface roughness device i.e. Profile meter (or) Mitutoyo Talysurf shown in figure2 is used to calculate the surface roughness. Profile meter is electronic, mere instrument must be used very cautiously. The instrument consist a probe and ruby tiny tip.

Figure2. Mitutoyo Talysurf Equipment

III. GREY TAGUCHI METHOD

It involves coupling of Taguchi method with grey relational analysis to solve more response optimization problems. It is primarily a quantitative analysis on dynamic process of the system. Generally GEA Y is used to optimize two machining characteristics simultaneously and Taguchi design is used to obtain the experimental results.

Steps involved in Grey based Taguchi method:-

1. Conduction of the experiments at different setting of parameters based on orthogonal array.
2. Normalization of experimental data in the range of 0 and1.
3. Calculation of grey relational coefficient.
4. Calculation of grey relational grade by averaging the individual grey relational coefficient. Based on the Grey relational grade the overall performance characteristic of the multiple responses can be calculated.

Step 1: Normalization of the responses (quality characteristics)

Here experimental data is to be normalized in the range of 0-1.As MRR is Higher-the-better (HB) and SR is lower-the-better criterion is selected.

A) Higher the better for MRR:

$$X_i(M) = \frac{Y_i(M) - \min Y_i(M)}{\max Y_i(M) - \min Y(M)}$$

B) Lower the better for SR:

$$X_i(M) = \frac{\max Y_i(M) - Y_i(M)}{\max Y_i(M) - \min Y_i(M)}$$

Step 2: Calculation of Grey relational coefficient

After normalizing the results of MRR and SR, the next step is the calculation of grey relational coefficient values for MRR and SR.

Grey relation coefficient (ε_i (M)) = $\frac{\Delta_{min} + \varphi \Delta_{max}}{\Delta_{oi}(M) + \varphi \Delta_{max}}$

Where Δ_{0i}=quality loss function $\Delta_{oi}(M) = [X_{oi}(M) - X_i(M)]$,

$X_{oi}(M)$ = Maximum normalized value

$X_i(M)$ Normalized values from i=1 to n

To larger the weaken impact, a distinguish coefficient 'Ψ' was used and it lies 0 to1. The considerable value of Ψ is 0.5, due to good stability and average distinguish effects.

Step 3: Calculation of Grey relational Grade and order

$$\text{Grey relational garde } (\gamma_i) = \frac{1}{n}\sum_{M=1}^{n} \varepsilon_i(M)$$

Where n=number of responses, ε_i (M) = Grey relational coefficient

a) **Calculation of signal to noise ratio**

In Taguchi method, S/N Ratio is the Statistical measuring process for predict the optimum factors to respected Responses. Analysis in this content has tended to identify the components, which are influencing the normal reaction The Smaller the better, Higher the better and Nominal the better are three sorts for the S/N Ratio, for examine the factor's enactment.

3.1Lower is better

In EDM process, the response characteristic such as surface roughness is considered as smaller for the better quality type.

$$S/N = -10\log_{10}\left(\frac{\sum y^2}{n}\right) \longrightarrow \quad (3.1)$$

3.2 Higher is better

In EDM process, the response characteristic such as material removal rate is considered as larger quality.

$$S/N = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{y2}\right) \longrightarrow \quad (3.2)$$

3.3 Nominal is better

In EDM process, the response characteristics which show the variation on the values from the lower to higher better performance.

$$S/N = -10\log\frac{1}{n}\sum(yi - S)2 \longrightarrow \quad (3.3)$$

IV. RESULTS OF TITANIUM GRADE 2 MATERIAL

The experiments were conducted work piece Titanium grade 2 material based on Taguchi L_{27} OA. The impact on the work piece by EDM is to see in figure 3 and its MRR and SR values in table 6.

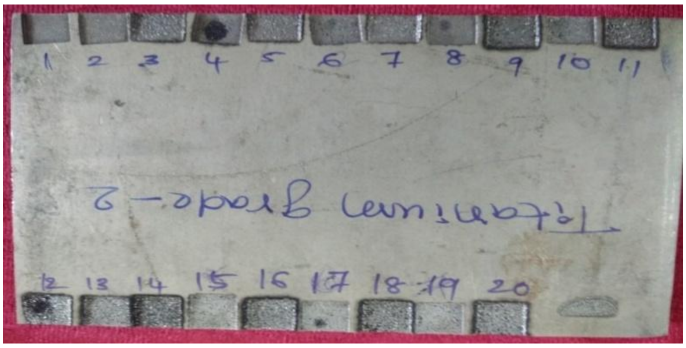


Figure3. Titanium grade 2 work piece after machining

V. EXPERIMEL RESULTS AND DISCUSSIONS

I Experimentation result of Titanium grade 2is shown in the below table 6.

Table 6. Experimentation result forTitanium grade 2

S .No	Current (Amp)	Pulse on time (μs)	Duty cycle (%)	Tool material	MRR (mg/min)	SR (μm)
1	6	100	10	Copper	0.006	2.3333
2	6	100	11	WCu	0.00744	2.3966
3	6	100	12	Graphite	0.003	3.6166
4	6	150	10	WCu	0.00555	2.8666
5	6	150	11	Graphite	0.00319	4.0266
6	6	150	12	Copper	0.0074	3.61
7	6	200	10	Graphite	0.00373	3.1966
8	6	200	11	Copper	0.00625	3.2766
9	6	200	12	WCu	0.00674	2.5833
10	8	100	10	Copper	0.00769	2.9233
11	8	100	11	WCu	0.00649	4.0633
12	8	100	12	Graphite	0.00555	3.9066
13	8	150	10	WCu	0.00865	3.0533
14	8	150	11	Graphite	0.00602	4.1666
15	8	150	12	Copper	0.0156	3.2166
16	8	200	10	Graphite	0.00714	3.9633
17	8	200	11	Copper	0.0128	3.4233
18	8	200	12	WCu	0.00759	4.2766
19	10	100	10	Copper	0.0125	3.3966
20	10	100	11	WCu	0.008	3.5633
21	10	100	12	Graphite	0.00555	3.73
22	10	150	10	WCu	0.01111	4.22
23	10	150	11	Graphite	0.00641	2.5666
24	10	150	12	Copper	0.01666	2.9666
25	10	200	10	Graphite	0.0075	2.83
26	10	200	11	Copper	0.0153	2.7233
27	10	200	12	WCu	0.00793	3.6833

6.2.2 RESULTS OF TITANIUM GRADE 5 MATERIAL

The experiments were conducted work piece Titanium grade 5 material based on Taguchi L_{27} OA. The impact on the work piece by EDM is to see in figure 4 and its MRR and SR values in table 7.

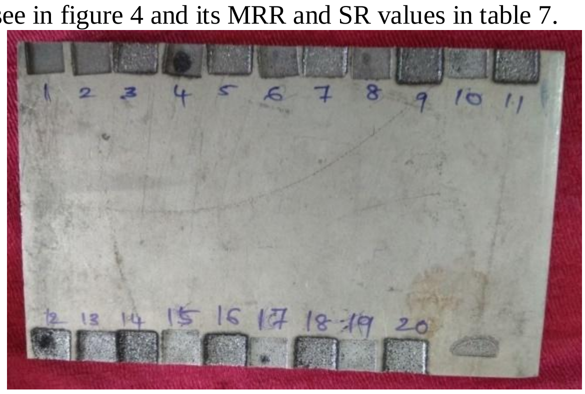


Figure 4. Titanium grade 5 work piece after machining

II Experimentation result of Titanium grade 5 is shown in the below table 7.

Table7. Experimentation result for Titanium grade 5

S.No	Current (Amp)	Pulse on time (µs)	Duty cycle (%)	Tool material	MRR (mg/min)	SR (µm)
1	6	100	10	Copper	0.004395	2.6633
2	6	100	11	WCu	0.004494	3.3267
3	6	100	12	Graphite	0.002822	3.2167
4	6	150	10	WCu	0.004295	2.4000
5	6	150	11	Graphite	0.003147	3.3200
6	6	150	12	Copper	0.004025	3.8467
7	6	200	10	Graphite	0.00334	2.9900
8	6	200	11	Copper	0.004037	2.1167
9	6	200	12	WCu	0.004878	2.5900
10	8	100	10	Copper	0.006	2.0200
11	8	100	11	WCu	0.004897	2.5033
12	8	100	12	Graphite	0.003764	4.1267
13	8	150	10	WCu	0.003623	2.4533
14	8	150	11	Graphite	0.003852	3.2867
15	8	150	12	Copper	0.005263	2.5133
16	8	200	10	Graphite	0.003036	4.2400
17	8	200	11	Copper	0.005644	3.3833
18	8	200	12	WCu	0.003797	3.3433
19	10	100	10	Copper	0.005769	3.0833
20	10	100	11	WCu	0.000746	3.4500
21	10	100	12	Graphite	0.002809	3.8400
22	10	150	10	WCu	0.003636	3.8033
23	10	150	11	Graphite	0.003889	3.1733
24	10	150	12	Copper	0.007143	2.3167
25	10	200	10	Graphite	0.003469	3.8833
26	10	200	11	Copper	0.006404	2.6867
27	10	200	12	WCu	0.010921	4.8267

a) SIGNAL TO NOISE RATIO FOR TITANIUM GRADE 2 MRR

The signal to noise ratios of Titanium grade 2 work material for MRR is shown in below table 8.

Table 8. Experimental results of MRR and their S/N ratio Titanium grade 2

S .No	Current (Amp)	Pulse on time (µs)	Pulse off time (µs)	Tool material	MRR (mg/min)	S/N ratio for MRR
1	6	100	10	Copper	0.006	-44.437
2	6	100	11	WCu	0.00744	-42.5685
3	6	100	12	Graphite	0.003	-50.4576
4	6	150	10	WCu	0.00555	-45.1141
5	6	150	11	Graphite	0.00319	-49.9242
6	6	150	12	Copper	0.0074	-42.6154
7	6	200	10	Graphite	0.00373	-48.5658
8	6	200	11	Copper	0.00625	-44.0824
9	6	200	12	WCu	0.00674	-43.4268
10	8	100	10	Copper	0.00769	-42.2815
11	8	100	11	WCu	0.00649	-43.7551
12	8	100	12	Graphite	0.00555	-45.1141
13	8	150	10	WCu	0.00865	-41.2597
14	8	150	11	Graphite	0.00602	-44.4081
15	8	150	12	Copper	0.0156	-36.1375
16	8	200	10	Graphite	0.00714	-42.926
17	8	200	11	Copper	0.0128	-37.8558
18	8	200	12	WCu	0.00759	-42.3952
19	10	100	10	Copper	0.0125	-38.0618
20	10	100	11	WCu	0.008	-41.9382
21	10	100	12	Graphite	0.00555	-45.1141
22	10	150	10	WCu	0.01111	-39.0857

23	10	150	11	Graphite	0.00641	-43.8628
24	10	150	12	Copper	0.01666	-35.5665
25	10	200	10	Graphite	0.0075	-42.4988
26	10	200	11	Copper	0.0153	-36.3062
27	10	200	12	WCu	0.00793	-42.0145

b) SIGNAL TO NOISE RATIO FOR TITANIUM GRADE 2 SR

The signal to noise ratios of Titanium grade 2 work material for SR is shown in below table 9.

Table 9. Experimental results of SR and their S/N ratio Titanium grade 2

S .No	Current (Amp)	Pulse on time (µs)	Pulse off time (µs)	Tool material	SR (µm)	S/N ratio for SR
1	6	100	10	Copper	2.3333	-7.35954
2	6	100	11	WCu	2.3966	-7.59215
3	6	100	12	Graphite	3.6166	-11.1662
4	6	150	10	WCu	2.8666	-9.14754
5	6	150	11	Graphite	4.0266	-12.0989
6	6	150	12	Copper	3.61	-11.1501
7	6	200	10	Graphite	3.1966	-10.0939
8	6	200	11	Copper	3.2766	-10.3086
9	6	200	12	WCu	2.5833	-8.24361
10	8	100	10	Copper	2.9233	-9.31757
11	8	100	11	WCu	4.0633	-12.1776
12	8	100	12	Graphite	3.9066	-11.8361
13	8	150	10	WCu	3.0533	-9.69548
14	8	150	11	Graphite	4.1666	-12.3958
15	8	150	12	Copper	3.2166	-10.1481
16	8	200	10	Graphite	3.9633	-11.9612
17	8	200	11	Copper	3.4233	-10.689
18	8	200	12	WCu	4.2766	-12.6221
19	10	100	10	Copper	3.3966	-10.6211
20	10	100	11	WCu	3.5633	-11.0371
21	10	100	12	Graphite	3.73	-11.4342
22	10	150	10	WCu	4.22	-12.5062
23	10	150	11	Graphite	2.5666	-8.18739
24	10	150	12	Copper	2.9666	-9.44538
25	10	200	10	Graphite	2.83	-9.03573
26	10	200	11	Copper	2.7233	-8.70202
27	10	200	12	WCu	3.6833	-11.3248

c) GREY TAGUCHI PROCEDURE TO OPTIMIZE TITANIUM GRADE 2

To optimize the MRR and SR values with using of Grey Taguchi technique, find the Normalized vector and Grey relation coefficient are shown in table 10 and 11 for MRR and SR respectively. Optimization result grade and order is shown in below table 12.

Table 10. Normalized vector values and Grey relation coefficient values for MRR Ti grade 2

S.NO	MRR (mg/min)	Normalized vector for MRR values	Grey relation coefficient for MRR values
1	0.006	0.2196	0.3905
2	0.00744	0.3250	0.4255
3	0.003	0.0000	0.3333
4	0.00555	0.1867	0.3807
5	0.00319	0.0139	0.3365
6	0.0074	0.3221	0.4245
7	0.00373	0.0534	0.3456
8	0.00625	0.2379	0.3962
9	0.00674	0.2738	0.4078
10	0.00769	0.3433	0.4323
11	0.00649	0.2555	0.4018
12	0.00555	0.1867	0.3807
13	0.00865	0.4136	0.4602
14	0.00602	0.2211	0.3910

15	0.0156	0.9224	0.8657
16	0.00714	0.3031	0.4177
17	0.0128	0.7174	0.6389
18	0.00759	0.3360	0.4296
19	0.0125	0.6955	0.6215
20	0.008	0.3660	0.4409
21	0.00555	0.1867	0.3807
22	0.01111	0.5937	0.5517
23	0.00641	0.2496	0.3999
24	0.01666	1.0000	1.0000
25	0.0075	0.3294	0.4271
26	0.0153	0.9004	0.8339
27	0.00793	0.3609	0.4389

Table 11 Normalized vector values and Grey relation coefficient values for SR Ti grade 2

S.NO	SR in micro meters	Normalized vector for SR values	Grey relation coefficient for SR values
1	2.3333	1.0000	1.0000
2	2.3967	0.9674	0.9388
3	3.6167	0.3396	0.4309
4	2.8667	0.7255	0.6456
5	4.0267	0.1286	0.3646
6	3.6100	0.3430	0.4322
7	3.1967	0.5557	0.5295
8	3.2767	0.5146	0.5074
9	2.5833	0.8713	0.7953
10	2.9233	0.6964	0.6222
11	4.0633	0.1097	0.3596
12	3.9067	0.1904	0.3818
13	3.0533	0.6295	0.5744
14	4.1667	0.0566	0.3464
15	3.2167	0.5454	0.5238
16	3.9633	0.1612	0.3735
17	3.4233	0.4391	0.4713
18	4.2767	0.0000	0.3333
19	3.3967	0.4528	0.4775
20	3.5633	0.3670	0.4413
21	3.7300	0.2813	0.4103
22	4.2200	0.0291	0.3399
23	2.5667	0.8799	0.8063
24	2.9667	0.6741	0.6054
25	2.8300	0.7444	0.6617
26	2.7233	0.7993	0.7136
27	3.6833	0.3053	0.4185

Grade and Order values represents the optimal parameters for Titanium Grade 2 material

Table 12. Grade and Order values

S. No	Grade	Order
1	0.6952	3
2	0.6822	5
3	0.3821	22
4	0.5132	13
5	0.3505	27
6	0.4283	19
7	0.4376	17
8	0.4518	14
9	0.6015	7
10	0.5272	11
11	0.3807	25

12	0.3812	24
13	0.5173	12
14	0.3687	26
15	0.6947	4
16	0.3956	20
17	0.5551	8
18	0.3814	23
19	0.5495	9
20	0.4411	16
21	0.3955	21
22	0.4458	15
23	0.6031	6
24	**0.8027**	**1**
25	0.5444	10
26	0.7738	2
27	0.4287	18

d) SIGNAL TO NOISE RATIO FOR TITANIUM GRADE 5 MRR

The signal to noise ratios of titanium grade 5 work material for MRR is shown in below table 13.

Table 13.Experimental results of MRR and their S/N ratio Ti grade 5

S .No	Current (Amp)	Pulse on time (μs)	Pulse off time (μs)	Tool material	MRR (mg/min)	S/N ratio for MRR
1	6	100	10	Copper	0.004395	-47.1413
2	6	100	11	WCu	0.004494	-46.9480
3	6	100	12	Graphite	0.002822	-50.9888
4	6	150	10	WCu	0.004295	-47.3410
5	6	150	11	Graphite	0.003147	-50.0419
6	6	150	12	Copper	0.004025	-47.9040
7	6	200	10	Graphite	0.00334	-49.5261
8	6	200	11	Copper	0.004037	-47.8777
9	6	200	12	WCu	0.004878	-46.2351
10	8	100	10	Copper	0.006	-44.4370
11	8	100	11	WCu	0.004897	-46.2013
12	8	100	12	Graphite	0.003764	-48.4869
13	8	150	10	WCu	0.003623	-48.8182
14	8	150	11	Graphite	0.003852	-48.2866
15	8	150	12	Copper	0.005263	-45.5751
16	8	200	10	Graphite	0.003036	-50.3529
17	8	200	11	Copper	0.005644	-44.9682
18	8	200	12	WCu	0.003797	-48.4101
19	10	100	10	Copper	0.005769	-44.7776
20	10	100	11	WCu	0.000746	-62.5421
21	10	100	12	Graphite	0.002809	-51.0290
22	10	150	10	WCu	0.003636	-48.7867
23	10	150	11	Graphite	0.003889	-48.2035
24	10	150	12	Copper	0.007143	-42.9226
25	10	200	10	Graphite	0.003469	-49.1965
26	10	200	11	Copper	0.006404	-43.8712
27	10	200	12	WCu	0.010921	-39.2347

e) SIGNAL TO NOISE RATIO FOR TITANIUM GRADE 5 SR

The signal to noise ratios of titanium grade 5 work material for SR is shown in below table 14.

Table14. Experimental results of SR and their S/N ratio Ti grade 5

S .No	Current (Amp)	Pulse on time (μs)	Pulse off time (μs)	Tool material	SR (μm)	S/N ratio for SR
1	6	100	10	Copper	2.6633	-8.50851
2	6	100	11	WCu	3.3267	-10.4402
3	6	100	12	Graphite	3.2167	-10.1481
4	6	150	10	WCu	2.4000	-7.60422

5	6	150	11	Graphite	3.3200	-10.4228
6	6	150	12	Copper	3.8467	-11.7017
7	6	200	10	Graphite	2.9900	-9.51342
8	6	200	11	Copper	2.1167	-6.51305
9	6	200	12	WCu	2.5900	-8.266
10	8	100	10	Copper	2.0200	-6.10703
11	8	100	11	WCu	2.5033	-7.97037
12	8	100	12	Graphite	4.1267	-12.312
13	8	150	10	WCu	2.4533	-7.79513
14	8	150	11	Graphite	3.2867	-10.3351
15	8	150	12	Copper	2.5133	-8.005
16	8	200	10	Graphite	4.2400	-12.5473
17	8	200	11	Copper	3.3833	-10.5869
18	8	200	12	WCu	3.3433	-10.4836
19	10	100	10	Copper	3.0833	-9.78041
20	10	100	11	WCu	3.4500	-10.7564
21	10	100	12	Graphite	3.8400	-11.6866
22	10	150	10	WCu	3.8033	-11.6033
23	10	150	11	Graphite	3.1733	-10.0303
24	10	150	12	Copper	2.3167	-7.29727
25	10	200	10	Graphite	3.8833	-11.7841
26	10	200	11	Copper	2.6867	-8.58428
27	10	200	12	WCu	4.8267	-13.6729

f) GREY TAGUCHI PROCEDURE TO OPTIMIZE TITANIUM GRADE 5

To optimize the MRR and SR values with using of Grey Taguchi technique, find the Normalized vector and Grey relation coefficient are shown in table 15 and 16 for MRR and SR respectively. Optimization result grade and order is shown in below table 17.

Table 6.12. Normalized vector values and Grey relation coefficient values for MRR Ti grade 5

S.NO	MRR (mg/min)	Normalized vector for MRR values	Grey relation Coefficient for MRR values
1	0.004395	0.3586	0.4381
2	0.004494	0.3683	0.4418
3	0.002822	0.2040	0.3858
4	0.004295	0.3488	0.4343
5	0.003147	0.2360	0.3956
6	0.004025	0.3223	0.4246
7	0.00334	0.2549	0.4016
8	0.004037	0.3235	0.4250
9	0.004878	0.4061	0.4571
10	0.006	0.5164	0.5083
11	0.004897	0.4080	0.4579
12	0.003764	0.2966	0.4155
13	0.003623	0.2828	0.4108
14	0.003852	0.3052	0.4185
15	0.005263	0.4439	0.4735
16	0.003036	0.2251	0.3922
17	0.005644	0.4814	0.4909
18	0.003797	0.2999	0.4166
19	0.005769	0.4937	0.4969
20	0.000746	0.0000	0.3333
21	0.002809	0.2028	0.3854
22	0.003636	0.2841	0.4112
23	0.003889	0.3089	0.4198
24	0.007143	0.6287	0.5738
25	0.003469	0.2676	0.4057
26	0.006404	0.5561	0.5297
27	0.010921	1.0000	1.0000

Table 16. Normalized vector values and Grey relation coefficient values for SR Ti grade 5

S.NO	SR in micro meters	Normalized vector for MRR values	Grey relationCoefficient for MRR values
1	2.6633	0.7708	0.6857
2	3.3267	0.5344	0.5178
3	3.2167	0.5736	0.5397
4	2.4000	0.8646	0.7869
5	3.3200	0.5368	0.5191
6	3.8467	0.3492	0.4345
7	2.9900	0.6544	0.5913
8	2.1167	0.9656	0.9356
9	2.5900	0.7969	0.7111
10	2.0200	1.0000	1.0000
11	2.5033	0.8278	0.7438
12	4.1267	0.2494	0.3998
13	2.4533	0.8456	0.7641
14	3.2867	0.5487	0.5256
15	2.5133	0.8242	0.7399
16	4.2400	0.2090	0.3873
17	3.3833	0.5142	0.5072
18	3.3433	0.5285	0.5147
19	3.0833	0.6211	0.5689
20	3.4500	0.4905	0.4953
21	3.8400	0.3515	0.4354
22	3.8033	0.3646	0.4404
23	3.1733	0.5891	0.5489
24	2.3167	0.8943	0.8255
25	3.8833	0.3361	0.4296
26	2.6867	0.7625	0.6779
27	4.8267	0.0000	0.3333

Grade and Order values represents the optimal parameters for Titanium Grade 5 material

Table 17. Grade and Order values Ti grade 5

S. No	Grade	Order
1	0.5619	11
2	0.4798	16
3	0.4628	19
4	0.6106	5
5	0.4573	20
6	0.4295	21
7	0.4964	13
8	0.6803	3
9	0.5841	10
10	**0.7542**	**1**
11	0.6008	8
12	0.4076	26
13	0.5874	9
14	0.4720	17
15	0.6067	6
16	0.3897	27
17	0.4990	14
18	0.4656	18
19	0.5329	12
20	0.4143	24
21	0.4104	25
22	0.4258	22

23	0.4843	15
24	0.6997	2
25	0.4176	23
26	0.6038	7
27	0.6667	4

V. GRADE PLOTS AND ANOVA

a) GRADE PLOTS

After the grey relational grade is obtained the data was analyzed. In order to investigate the effects of process parameters on MRR and SR, experiments are conducted based on L27 OA. An interaction plot shows that by changing the settings of one factor, due to its impact another factor also changes. Because an interaction can magnify or diminish main effects, evaluating interactions is extremely important.

MAIN EFFECTS PLOT AND INTERACTION PLOT FOR MEANS FOR GRADE 2

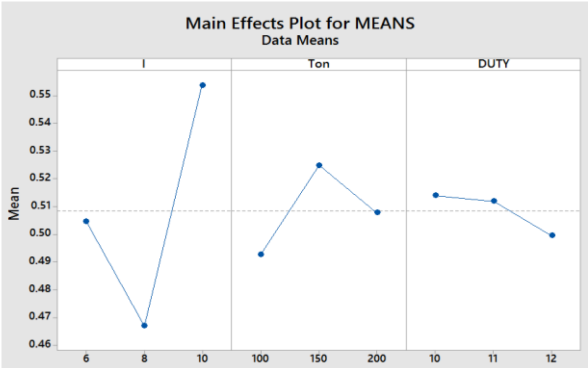


Figure5:Effecct of process parametersa on MRR

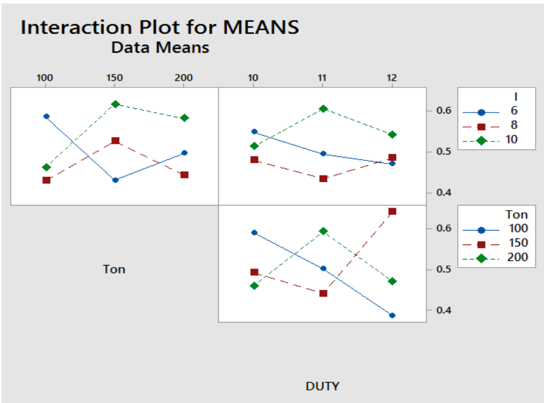
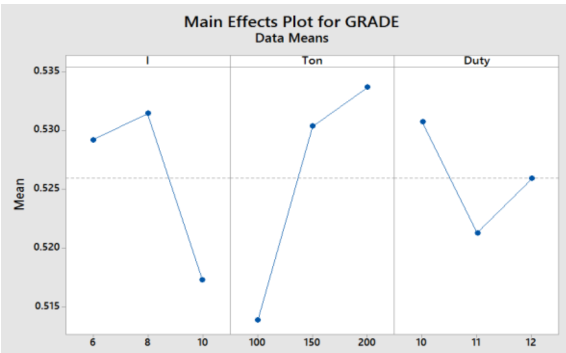


Figure6: Interaction plots for means

From the above plot optimized results for the output are obtained at $A_3B_2C_1$ i.e. 10amp, 150µs, 12%.

MAIN EFFECTS PLOT AND INTERACTION PLOT FOR MEANS FOR GRADE 5



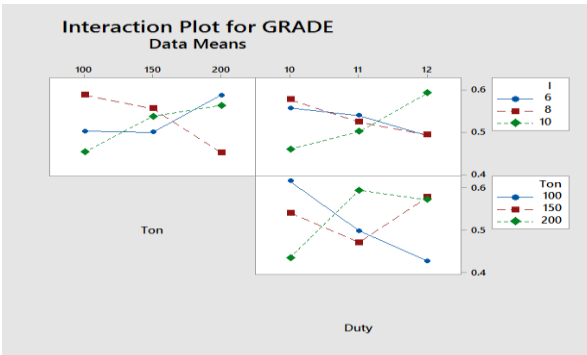


Figure 7: Effect of process parameters on MRR

Figure 8: Interaction plots for means

From the above plot optimized results for the output are obtained at $A_2B_3C_1$ i.e. 8amp, 200µs, 10%.

b) ANOVA

The full form of 'ANOVA' is Analysis Of Variance. It is an independent decision making tool which is majorly depends upon statistics. It is used to know the variance in mean of tested factors with their corresponding level. But the ANOVA gives the impact of the all Control factors and their interactions with respect to their Responses

ANOVA TABLE FOR MRR FOR THE TITANIUM GRADE 2 WORK-PIECE MACHINING ON EDM

Table 7.1 Anova MRR table for titanium grade 2

Source	DF	Adj SS	Adj MS	F-Value	P-Value
I	2	0.000100	0.000050	4.55	0.023
Ton	2	0.000020	0.000010	0.89	0.425
DUTY	2	0.000002	0.000001	0.10	0.906
Error	20	0.000221	0.000011		
Total	26	0.000343			

Regression Equation

MRR in mg/min = $0.008066 - 0.002589\, I\_6 + 0.000548\, I\_8 + 0.002040\, I\_10 - 0.001153\, Ton\_100 + 0.000888\, Ton\_15 + 0.000265\, Ton\_200 - 0.000303\, DUTY\_10 - 0.000077\, DUTY\_11 + 0.000380\, DUTY\_12$ (1)

ANOVA TABLE FOR SR FOR THE TITANIUM GRADE 2 WORK-PIECE MACHINING ON EDM

Table 7.2 Anova SR table for titanium grade 2

Source	DF	Adj SS	Adj MS	F-Value	P-Value
I	2	1.48137	0.74069	2.14	0.144
Ton	2	0.04171	0.02085	0.06	0.942
DUTY	2	0.43766	0.21883	0.63	0.542
Error	20	6.92549	0.34627		
Total	26	8.88623			

Regression Equation

SR = $3.355 - 0.254\, I\_6 + 0.311\, I\_8 - 0.057\, I\_10 - 0.029\, Ton\_100 + 0.056\, Ton\_150 - 0.026\, Ton\_200 - 0.157\, DUTY\_10 + 0.001\, DUTY\_11 + 0.155\, DUTY\_12$ (2)

ANOVA TABLE FOR MRR FOR THE TITANIUM GRADE 5 WORK-PIECE MACHINING ON EDM

Table 7.3 Anova MRR table for titanium grade 5

Source	DF	Adj SS	Adj MS	F-Value	P-Value
I	2	0.000005	0.000002	0.67	0.522
Ton	2	0.000006	0.000003	0.77	0.476
DUTY	2	0.000005	0.000002	0.67	0.523
Error	20	0.000072	0.000004		
Total	26	0.000088			

Regression Equation

MRR = 0.004448 - 0.000511 I_6 - 0.000017 I_8 + 0.000528 I_10 - 0.000482 Ton_100 - 0.000129 Ton_150 + 0.000610 Ton_200 - 0.000274 DUTY_10 - 0.000325 DUTY_11 + 0.000599 DUTY_12 (3)

ANOVA TABLE FOR SR FOR THE TITANIUM GRADE 5 WORK-PIECE MACHINING ON EDM

Table 7.4 Anova SR table for titanium grade 2

Source	DF	Adj SS	Adj MS	F-Value	P-Value
I	2	1.2317	0.6158	1.19	0.325
Ton	2	0.4918	0.2459	0.48	0.628
DUTY	2	0.7768	0.3884	0.75	0.485
Error	20	10.3458	0.5173		
Total	26	12.8460			

Regression Equation

$$SR = 3.163 - 0.222\, I\_6 - 0.066\, I\_8 + 0.288\, I\_10 - 0.026\, Ton\_100 - 0.150\, Ton\_150 + 0.177\, Ton\_200 - 0.103\, DUTY\_10 - 0.136\, DUTY\_11 + 0.239\, DUTY\_12 \quad (4)$$

VI. CONCLUSION

Finally the investigational work is done in EDM machine.Based on the L27 orthogonal array, Ton, Duty cycle, tool material and current are taken as i/p parameters. The effect of process parameters on outputs of the EDM process are optimized and obtained maximum material removal rate (MRR) and best surface roughness (R_a) by using Grey Taguchi technique for two different materials. Grey Taguchi technique is used to solve multi objective functional equations.It is used to reduce overall equation to single form. By using this method the intentional outputs are enhanced. This method is ultimately used to improve overall quality and productivity. It is observed that the selected output largely affects the product and the quality of the product. ANOVA implies the contribution of the inputs to the output and variations in them.

- The optimal machining condition for Titanium grade 2 material with Grey Taguchi technique is at on of 10 Amp, pulse on time of 150 µ sec and duty cycle of 12 i.e. of $A_3B_2C_1$ for the material of Titanium grade2 material.
- The optimal machining condition for Titanium grade 5 with Grey Taguchi technique is at on of 8Amp, pulse on time of 200 µ sec and duty cycle of 10 i.e. of $A_2B_3C_1$ for the material of Titanium grade5 material.

REFERENCES

1.Jadi Laxman and Kotakonda Guru Raj. "Optimization of electric discharge machining process parameters using Taguchi technique" International journal of advanced mechanical engineering .ISSN 2250-3234 Volume 4, Number 7(2014), pp.729-739.

2.Shankar Singh, S. Maheshwari, P.C. Pandey. "Some investigations into the electric discharge machining of hardened tool steel using different electrode materials", Journal of Materials Processing Technology 149 (2004) 272–277, Accepted 17 November 2003

3. Lazarenko, B.R., 1943, "to invert the effect of wear on electric power contacts", desertion of the all-union institute for electro technique in Moscow/cccp, Russian.

4. Jain V.K. "Advanced Machining Processes" Allied Publishers Pvt. Limited, New Delhi, 2005.

5. Mcgeough, J.A, "Advanced methods of machining" London: Chapman and hall, 1998.

6. Ho K.H. and Newman S.T.,"State of the art electrical discharge machining (EDM)" International Journal of Machine Tools & Manufacture, 43 (2003): pp. 1287–1300.

7. M.Mahardika and K.Mitsui, "Total energy of discharge pulse calculations by stochastic methods", proceeding of the international Conference of the 10th AUN/SEED.net field wise seminar, Hanoi, Vietnam in 28th- 29th august 2007.

