IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

OPTIMIZATION OF EDM PARAMETERS USING TAGUCHI METHOD AND GREY RELATIONAL ANALYSIS FOR AISI 01 DIE STEEL

Trupti Raut *, Prof. M.Y. Shinde
* Mechanical Engg.Department, K.B.P.Collage, Satara, Maharashtra,India.
Mechanical Engg.Department, K.B.P.Collage, Satara, Maharashtra,India.

ABSTRACT

Optimization is the best method used in industrial area for increasing quality of product by lowering the cost of product. In this paper, the experimental investigation of material removal rate, electrode wear rate, surface roughness, radial overcut and half taper angle during machining on OHNS Die steel by using Copper electrode on EDM machine is done. The input parameters used for experimental work are Peak Current (I_p), Pulse-On Time (T_{on}), Gap Voltage (V_g) and Sensitivity (Sen).Based on the experiments conducted on L9 Orthogonal array , optimization has been carried out by using Taguchi method (Single optimization) as well as Grey Relational Analysis (Multi-response optimization).Firstly single optimization has been carried out and then Multi-response optimization has been carried out. For that Grey relational generation and coefficient are find out and then Grey relational grade is carried out. Then the confirmation experiments are carried out. And thus according to this machining parameters are carried out to be optimized for combined objectives of higher MRR, lower EWR, lower SR, lower ROC and lower T. The results obtained from this optimization shows that Grey Relational Analysis is very effective optimization technique than Taguchi method.

KEYWORDS: EDM, Taguchi method, Orthogonal Array, ANOVA, Grey Relational Analysis.

INTRODUCTION

Electro Discharge Machining is a thermoelectric process in which removal of material takes place due to spark produced in between work-piece and electrode. For this spark production, both work piece and electrode are conductors of electricity. To understand experimental characteristics of OHNS Die steel , experimental study is carried out on it in this paper. P. Narender Singh, K. Raghukandan, B.C. Pai [1] in their paper carried out the study on the optimization by Grey relational analysis of EDM parameters on machining Al–10%SiCP composites. S V Subrahmanyam, M. M. M. Sarcar [2] in their work , machining on H13 Hot Die steel is carried out by multi-response optimization. In this paper, work is carried out on OHNS Die Steel (AISI-01) with the help of Copper electrode. Through hole of 10mm diameter and 4mm depth is done on the work piece. The process parameters such as Peak Current (I_p), Pulse-On Time (T_{on}), Gap Voltage (V_g) and Sensitivity (Sen) were optimized by using Multi Response optimization method i.e. by Grey Relational Analysis.

MATERIALS AND METHODS

[A]Material and Machine :-

AISI-01 Die Steel is used as work-piece and copper electrode is used as tool electrode. The photographic view of AISI-01Die Steel is shown in Fig. 1 and material properties are shown in table 2.1:-

Figure(1): Photographic View of AISI-01 Die Steel

Properties	Value
Melting Point	1421^0 C
Elastic Modulus (E)	193 G Pa
Conductivity	30.0 W/Mk
Density	7.81 g/cm^3

Table 2.1: Properties of OHNS Die Steel

Machining was carried out by using ELECTRA PULSE M3 machine in the company named Maharashtra Scooters Ltd. , Satara. Following table 2.2 shows specifications of machines and table 2.3 shows the working conditions and description of EDM machine :-

Description	Details
Supply Voltage	415 V
Discharge Current	35 A
Servo-system	Electromechanical

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Model	ELECTRONICA

Table 2.2: Specification of EDM Machine

Working Conditions	Description
Work-piece	OHNS Die Steel
Electrode	Copper
Peak Current	5,7,9 A
Pulse-on Time	50,100,150 µs
Gap Voltage	38,45,50 V
Sensitivity	7,8,9
Dielectric medium	EDM Oil

Table 2.3: Working conditions and Descriptions of EDM

Following table 2.4 shows the four different control parameters with three different levels :-

Control Parameters	Levels		
	1	2	3
Peak Current	5	7	9
Pulse-on Time	50	100	150
Gap Voltage	38	45	50
Sensitivity	7	8	9

Table 2.4: Control Parameters with three different Levels

EXPERIMENTAL DETAILS

The design of experiment (D.O.E.) chosen for the EDM of AISI-01 Die Steel was a Taguchi L9 orthogonal array and analysis was done by Taguchi as well as Grey Relational Analysis, by carrying out total number of 9 experiments along with 5 verification experiments. Following Table 3.1 shows L9 Orthogonal Array with experiments conducted represented by 4 columns and 3 different levels. And Table 3.2 shows L9 design matrix .

Expt. No.	Factor - 1	Factor – 2	Factor - 3	Factor - 4
E1	1	1	1	1
E2	1	2	2	2
E3	1	3	3	3
E4	2	1	2	3
E5	2	2	3	1
E6	2	3	1	2
E7	3	1	3	2
E8	3	2	1	3
E9	3	3	2	1

Table 3.1 : L9 Orthogonal Array Design matrix

Expt. No.	Factor - 1	Factor – 2	Factor - 3	Factor - 4
E1	5	50	38	7
E2	5	100	45	8
E3	5	150	50	9
E4	7	50	45	9
E5	7	100	50	7
E6	7	150	38	8
E7	9	50	50	8
E8	9	100	38	9
E9	9	150	45	7

Table 3.2: L9 Orthogonal Array Design matrix

In this work , a through hole of diameter 10 mm , 4mm depth was produced on OHNS Die Steel plate of size 100x50x4 mm. The process parameters chosen for study were Peak Current (I_p), Pulse-on Time (T_{on}), Gap Voltage (V_g) and Sensitivity (Sen) with above three different levels. Following were the performance parameters considered in this study: [1] Material Removal Rate (MRR) , [2] Electrode Wear Rate (EWR), [3] Surface Roughness (SR), [4] Radial Overcut (ROC), [5] Half Taper Angle (α^0). For these parameters, weights of work-piece and electrode were weighed before and after machining. Surface Roughness were measured by Surface Roughness Tester. For ROC, top diameter and electrode diameter were measured and for taper angle top diameter as well as bottom diameter were measured by Micrometer.

EXPERIMENTAL RESULTS

The results found by above formulae were tabulated in the following table 4.1 :-

Ex pt.	MRR (mm^3/ min)	EWR (mm^3/ min)	SR (µm)	ROC (mm)	Half Taper Angle (Degree)
E1	3.8591	0.0219	2.180	0.075	0.2865
E2	10.4822	0.0957	2.084	0.08	0.2149
E3	10.6254	0.0507	2.387	0.11	0.2865
E4	11.8021	0.3283	2.475	0.155	0.6446
E5	13.9521	0.1594	2.213	0.11	0.2865
E6	15.5225	0.4134	2.803	0.13	0.1432
E7	12.1255	0.1653	2.956	0.145	0.6446
E8	15.0416	0.3005	3.125	0.15	0.2149
E9	19.4268	0.2232	2.648	0.14	0.5013

Table 4.1 : Experimental Results

ANALYSIS OF EXPERIMENTS

From the experimental results , optimization was done by Taguchi method (Single Optimization) and Grey Relational Analysis (Multi-Response Optimization) and according to that verification experiments were carried out and from that objective of this study was to obtain higher MRR, lower EWR, SR, ROC and Half Taper Angle.

[1] Optimization by using Taguchi Method (Single Optimization Technique) :-

The analysis by Taguchi method (Single Optimization Technique) was done by following steps :-

Ex pt. No .	MRR (mm^3/ min)	EWR (mm^3/ min)	SR (µm)	ROC (mm)	Half Taper Angle (Degree)
E1	11.729	33.191	- 6.769	22.498	10.857
E2	20.409	20.381	- 6.378	21.938	13.355
E3	20.526	25.899	- 7.557	19.172	10.857
E4	21.439	9.6746	- 7.871	16.193	3.8142
E5	22.892	15.950	- 6.899	19.172	10.857
E6	23.819	7.6726	- 8.952	17.721	16.881
E7	21.674	15.634	- 9.414	16.772	3.8142
E8	23.545	10.443	- 9.897	16.478	13.355
E9	25.768	13.026	- 8.458	17.077	5.9980

Table 5.1.1: Signal-to-Noise Ratios

[1] Effect of input factors on MRR :-

The response table for MRR was as shown in table 5.1.2 and corresponding table for ANOVA was as shown in table 5.1.3.

Level	Peak Current (Ip)	Pulse-on Time (Ton)	Gap Voltage (Vg)	Sensitivi ty (Sen)
1	17.5552	18.2809	19.6982	20.1302
2	22.7171	22.2825	**22.5387**	**21.9674**
3	**23.6626**	**23.3717**	21.6979	21.8373
Delta	6.1074	5.0905	2.8405	1.8372
Rank	1	2	3	4

Table 5.1.2 : Response Table For MRR

Sources	D.O.F.	Sum of Squares	Mean Square	% Contributi on
Ip	2	64.8395	31.4198	**51.0419**
Ton	2	43.1117	21.5559	33.9377
Vg	2	12.7742	6.3871	10.0559
Sen	2	6.3064	3.1532	4.9844
Total	8	127.018	63.516	100

Table 5.1.3 : ANOVA Table for MRR

Therefore, Peak Current has maximum effect on material removal rate.

[2] Effect of input factors on EWR :-

The response table for EWR was as shown in table 5.1.4 and corresponding table for ANOVA was as shown in table 5.1.5.

Level	Peak Current (Ip)	Pulse-on Time (Ton)	Gap Voltage (Vg)	Sensitivi ty (Sen)
1	**26.4909**	**19.5001**	17.1023	**20.7225**
2	11.0991	15.5917	14.3608	14.5630
3	13.0346	15.5328	**19.1615**	15.3392
Delta	15.3918	3.9673	4.8007	6.1595
Rank	1	4	3	2

Table 5.1.4 : Response Table For EWR

Sources	D.O.F.	Sum of Squares	Mean Square	% Contrib ution
Ip	2	421.7257	210.86	**75.9772**
Ton	2	31.0185	15.5093	5.5882
Vg	2	34.8028	17.4014	6.2194
Sen	2	67.5218	33.7609	12.1646
Total	8	555.0688	277.5316	100

Table 5.1.5 : ANOVA Table for EWR

Therefore, Peak Current has maximum effect on electrode wear rate.

[3] Effect of input factors on SR :-

The response table for SR was as shown in table 5.1.6 and corresponding table for ANOVA was as shown in table 5.1.7.

Level	Peak Current (Ip)	Pulse-on Time (Ton)	Gap Voltage (Vg)	Sensitiv ity (Sen)
1	**-6.9014**	-8.0182	-8.5395	**-7.376**
2	-7.9079	**-7.7249**	**-7.5696**	-8.2482
3	-9.2568	-8.3229	-7.9569	-8.4418
Delta	2.3554	0.598	0.9699	1.0658
Rank	1	4	3	2

Table 5.1.6 : Response Table For SR

Sources	D.O.F.	Sum of Squares	Mean Square	% Contribut ion
Ip	2	8.3805	4.1903	**68.24**
Ton	2	0.5365	0.2683	4.37
Vg	2	1.4301	0.7151	11.64
Sen	2	1.9341	0.9671	15.75
Total	8	12.2812	6.1408	100

Table 5.1.7: ANOVA Table for SR

Therefore, Peak Current has maximum effect on surface roughness.

[4] Effect of input factors on ROC :-

The response table for ROC was as shown in table 5.1.8 and corresponding table for ANOVA was as shown in table 5.1.9.

Level	Peak Current (Ip)	Pulse-on Time (Ton)	Gap Voltage (Vg)	Sensitivity (Sen)
1	**21.2030**	**18.4833**	18.8993	**19.5828**
2	17.6955	19.1961	18.403	18.8106
3	16.7760	17.9902	**18.3722**	17.2812
Delta	4.427	1.2059	0.5271	2.3016
Rank	1	3	4	2

Table 5.1.8: Response Table For ROC

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Sources	D.O.F.	Sum of Squares	Mean Square	% Contribution
Ip	2	32.7464	16.37332	**74.92**
Ton	2	2.2033	1.1017	5.04
Vg	2	0.5252	0.2626	1.20
Sen	2	8.2327	4.1164	18.84
Total	8	43.7075	21.8539	100

Table 5.1.9 : ANOVA Table for ROC

Therefore, Peak Current has maximum effect on radial overcut.

[5] Effect of input factors on Half Taper Angle :-

The response table for Half Taper Angle was as shown in table 5.1.10 and corresponding table for ANOVA was as shown in table 5.1.11.

Level	Peak Current (Ip)	Pulse-on Time (Ton)	Gap Voltage (Vg)	Sensitivity (Sen)
1	**11.6901**	6.1620	**13.6980**	9.2377
2	10.5176	**12.5227**	7.7225	**11.3502**
3	7.7225	11.2455	8.5097	9.3423
Delta	3.9676	6.3607	5.9755	2.1125
Rank	3	1	2	4

Table 5.1.10 : Response Table For Half Taper Angle

Sources	D.O.F.	Sum of Squares	Mean Square	% Contribution
Ip	2	24.9292	12.4646	15.14
Ton	2	67.9317	39.9659	**41.26**
Vg	2	63.2447	31.6224	38.42
Sen	2	8.5053	4.2527	5.17
Total	8	164.6109	88.3056	100

Table 5.1.11: ANOVA Table for Half Taper Angle

Therefore, Pulse-on Time has maximum effect on Half Taper Angle.

Verification Experiments :-

After performing the statistical analysis on the experimental data, it has been observed that there is one particular level for each factor for which responses are either maximum (in case of MRR) or minimum (in case of EWR, SR, ROC, Half Taper Angle). According to that we get 5 different levels for which we get max. MRR and min. EWR,SR, ROC and Sen etc. The table of verification experiments was as follows :-

Physical Requirement	**Optimal Combination**			
	Ip	**Ton**	**Vg**	Sen
Max. MRR	9	50	45	8
Min. EWR	5	50	50	7
Min. SR	5	100	45	7
Min. ROC	5	100	38	7
Min. Half Taper Angle	5	100	38	8

Table 5.1.12: Optimal Parameter Settings of Input Factors

After performing verification experiments, we get the following experimental results :-

Ex	MRR (mm^3/ min)	EWR (mm^3/ min)	SR (μm)	ROC (mm)	Half Taper Angle (Degree)
1	**14.522**	0.7813	2.3225	0.125	1.0741
2	8.6762	**0.0301**	2.2275	0.095	1.1457
3	8.8464	0.0310	**2.1175**	0.09	1.5752
4	9.7040	0.0985	2.9898	**0.055**	0.7161
5	9.4514	0.2160	2.5714	0.095	**0.6445**

Table 5.1.13: Verification Experimental Results

[2]Optimization by using Grey Relational Analysis (Multi-response optimization Technique)

In this section, orthogonal array with Grey Relational Analysis was discussed i.e. muti-response optimization technique was used here. The optimization process was done by following steps :-

(1). In grey relational analysis , experimental data was first normalized in the range of 0 to 1. This process is known as grey relational generation.
According to the normalization two types of data normalization are done -
For Lower the better (LB) criteria ,

$$x_i(k) = \frac{\max y_i(k) - y_i(k)}{\max y_i(k) - \min y_i(k)}$$

For higher the better (HB) criteria,

$$x_i(k) = \frac{y_i(k) - \min y_i(k)}{\max y_i(k) - \min y_i(k)}$$

where $x_i(k)$ is the value after the Grey relational generation, min $y_i(k)$ is the smallest value of $y_i(k)$ for the k th response, and max $y_i(k)$ is the largest value of $y_i(k)$ for the k th response.The table 5.2.1 shows the normalized values.

Ex	MRR	EWR	SR	ROC	Taper Angle
1	0.0000	0.0000	0.1111	0.0000	0.4609
2	0.6182	0.5037	0.0000	0.0889	0.2698
3	0.6266	0.2867	0.3350	0.5276	0.4609
4	0.6916	0.9248	0.4244	1.0000	1.0000
5	0.7952	0.6780	0.1482	0.5276	0.4609
6	0.8612	1.0000	0.7316	0.7577	0.0000
7	0.7084	0.6904	0.8628	0.9081	1.0000
8	0.8417	0.8946	0.5912	0.9548	0.2698
9	1.0000	0.7930	0.5912	0.8598	0.8329

Table 5.2.1: Normalized S/N Ratio

(2). Calculate the deviation sequence.

$$\Delta_{oi}(k) = |\, y_{o(k)} - y_{i(k)} \,|$$

Where, yo(k) – Max. value of o/p of Normalized S/N

yi(k) – Value of o/p of Normalized S/N

Table 5.2.2 shows deviation sequence values

Ex	MRR	EWR	SR	ROC	Taper Angle
1	1.0000	1.0000	0.8889	1.0000	0.5391
2	0.3818	0.4963	1.0000	0.9111	0.7302
3	0.3734	0.7133	0.6650	0.4724	0.5391
4	0.3084	0.0752	0.5756	0.0000	0.0000
5	0.2048	0.322	0.8518	0.4724	0.5391
6	0.1388	0.0000	0.2684	0.2423	1.0000
7	0.2916	0.3096	0.1372	0.0919	0.0000
8	0.1583	0.1054	0.0000	0.0452	0.7309
9	0.0000	0.207	0.4088	0.1402	0.1671

Table 5.2.2: Deviation Sequence Table

(3). Calculate the Grey Relational coefficient .

$$\xi_i(k) = \frac{\Delta \min + \psi\Delta max}{\Delta 0i\ (k) + \psi\Delta max}$$

where,

$\Delta 0i\ (k)$ is the deviation sequence

Ψ is distinguishing coefficient which generally lies between 0 and 1. (It mostly 0.5)

Table 5.3.3 shows Grey Relational Coefficient

Ex	MRR	EWR	SR	ROC	Taper Angle
1	0.3333	0.3333	0.3599	0.3333	0.4812
2	0.5670	0.5019	0.3333	0.3543	0.4064
3	0.5725	0.4121	0.4292	0.5142	0.4811
4	0.6185	0.8693	0.4649	1.0000	1.0000
5	0.7094	0.6082	0.3699	0.5142	0.4812
6	0.7827	1.0000	0.6507	0.6736	0.3333
7	0.6316	0.6176	0.7847	0.8447	1.0000
8	0.7595	0.8259	1.0000	0.9171	0.4062
9	1.0000	0.7072	0.5502	0.7810	0.7495

Table 5.2.3: Grey Relational Coefficient

4. Now calculate Grey Relational Grade by averaging the Grey Relational coefficient.

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

where n = number of process responses.

Table 5.2.4 shows the Grey Relational Grade table.

Ex	Ip	Ton	Vg	Sen	Grade	Rank
1	5	50	38	7	0.3682	9
2	5	100	45	8	0.4326	8
3	5	150	50	9	0.4818	7
4	**7**	**50**	**45**	**9**	**0.7905**	**1**
5	7	100	50	7	0.5526	6
6	7	150	38	8	0.6881	5
7	9	50	50	8	0.7757	3
8	9	100	38	9	0.7817	2
9	9	150	45	7	0.7576	4

Table 5.2.4 Grey Relational Grade

(4) Performing statistical analysis of variance (ANOVA) for the input parameters with the Grey relational grade and to find which parameter significantly affects the process. Table 5.2.5 shows ANOVA table for G.R.G.

Input Factor	Average G.R.G. by Factor Level			
	Level-1	**Level-2**	**Level-3**	**Level-4**
Ip	0.4275	0.6771	**0.7717**	0.3442
Ton	**0.6448**	0.5890	0.6425	0.0558
Vg	0.6127	**0.6588**	0.6034	0.0554
Sen	0.5614	0.6321	**0.6847**	0.1233

Table 5.2.5 ANOVA table for G.R.G.

(5) Selecting the optimum levels of parameters. Table 5.2.6 shows the initial and optimal setting of parameters.

	Initial Parameter	Optimal Parameters	
		Prediction	**Experiment**
Setting Level	A1B1C1D1	A2B1C2D3	A2B1C2D3
MRR	3.8591		11.8021
EWR	0.0219		0.3283
SR	2.180		2.475
ROC	0.075		0.155
Taper angle	0.2865		0.6646
G.R.G.	0.3682	0.8838	0.7905

Improvement in Grey Relational Grade = 0.4223

Table 5.2.6 Results of initial and optimal parameters

(6) Conduct confirmation experiment and verify the optimal process parameters setting.

$$\alpha = \alpha_m + \sum_{i=1}^{q} (\alpha i - \alpha m)$$

where, α_m is the total mean of the Grey relational grade

α_i is the mean of the Grey relational grade at the optimal level and

q is the number of the machining parameters that significantly affects the multiple response characteristics.

RESULTS AND DISCUSSION

[1] Results are discussed here which are obtained from optimization by Taguchi Method i.e. by Single Optimization Technique :-

Experimental study was conducted to see the effect of Peak current, Pulse-on time, Gap Voltage and Sensitivity on the EDM performance of AISI-01 material. The variation of MRR, EWR, SR, ROC and T with respect to independent parameter considered for this study has being carried out.

(I)Effect of input factors on MRR :-

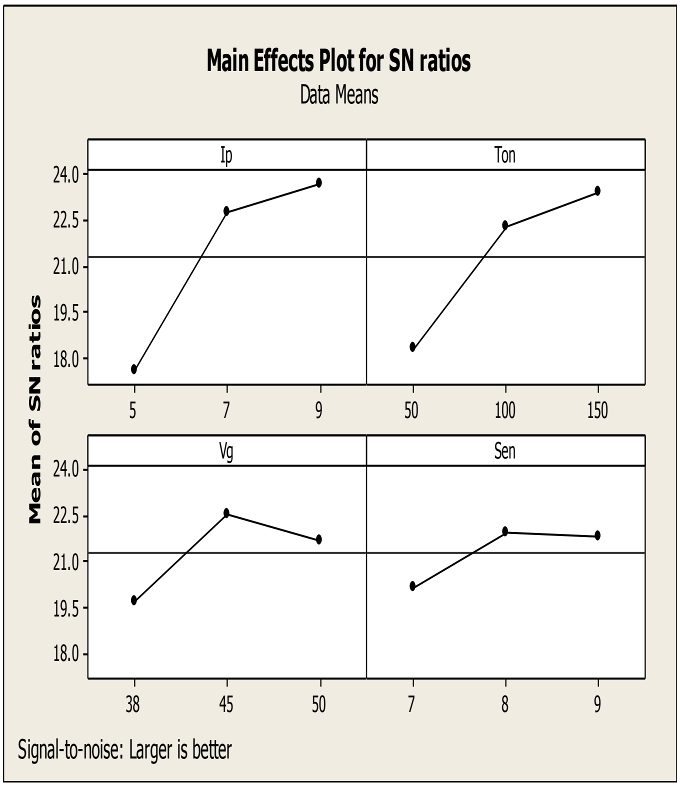

Figure 6.1.1 S/N Ratio curve for MRR with Ip, Ton, Vg, Sen

From fig. 6.1.1, it is observed that in case of Peak current , it is minimum for 5 Amp and it goes on increasing up to 9 Amp. In case of Pulse-on Time, it is minimum for 50 µs and maximum for 150 µs. In case of Gap voltage, it gets increasing from 38 to 45 Volt but again decreases from 45 to 50 Volt. Similarly, in case of Sensitivity , same condition happens. For higher MRR, Peak current has maximum contribution i.e. 51.04 %. And it is followed by Pulse –on Time and Gap voltage. And it is less affected by sensitivity i.e. 4.98 %.

(II) Effect of input factors on EWR :-

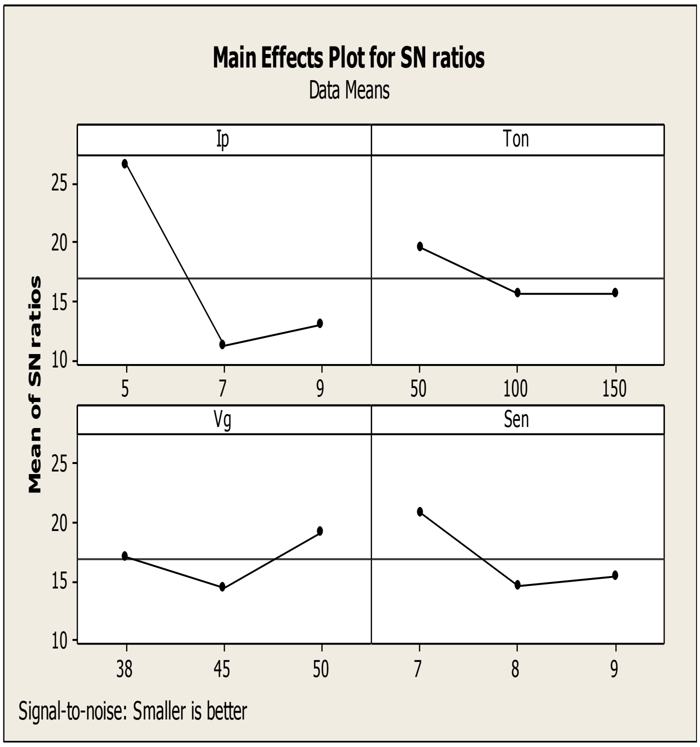

Figure 6.1.2 S/N Ratio curve for EWR with Ip,Ton,Vg,Sen

From fig. 6.1.2, it is observed that in case of Peak current , it is maximum for 5 Amp and it goes on decreasing up to 7Amp and again increases only up to 9 Amp.. In case of Pulse-on Time, it is maximum for 50 µs and up to 100, it comes down and from 100 to 150 µs , it remains same. In case of Gap voltage, it is minimum for 38 and maximum for 50 Volt. Similarly, in case of Sensitivity , it is maximum for 7 and comes down up to 8 and slightly increases up to 9. For lower EWR, Peak current has maximum contribution i.e. 75.97 %. And it is followed by sensitivity and Gap voltage. And it is less affected by Pulse-on time i.e. 5.58 %.

(III) Effect of input factors on SR :-
From fig. 6.1.3, it is observed that in case of Peak current , it is maximum for 5 Amp and minimum for 9 Amp.. In case of Pulse-on Time, it goes on increasing from 50 to 100 µs and again decreases from 100 to 150 µs . In case of Gap voltage, it goes on increasing from 38 to 45 Volt and again decreases from 45 to 50 Volt. Similarly, in case of Sensitivity , it is maximum for 7 and comes down up to 8 and again slightly decreases up to 9. For lower SR, Peak current has maximum contribution i.e. 68.24 %. And it is followed by sensitivity and Gap voltage. And it is less affected by Pulse-on time i.e. 4.37 %.

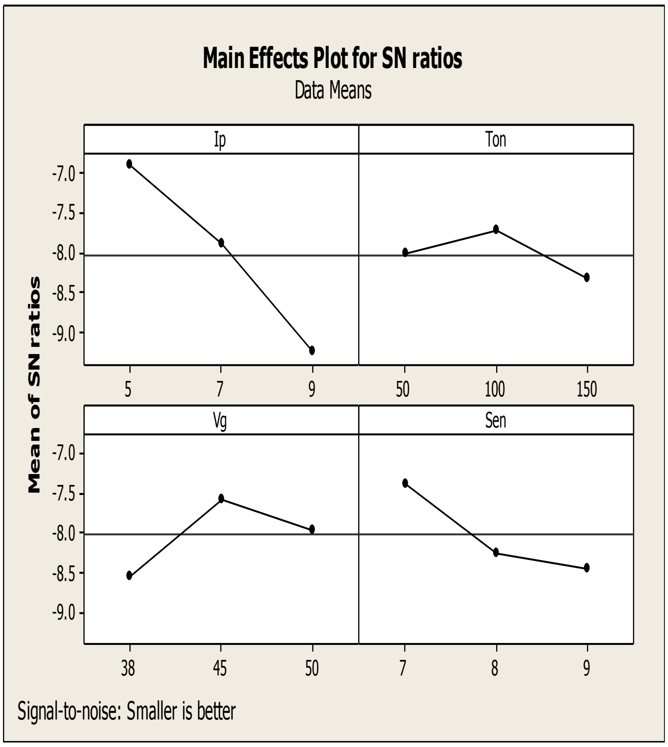

Figure 6.1.3 S/N Ratio curve for MRR with Ip, Ton, Vg, Sen

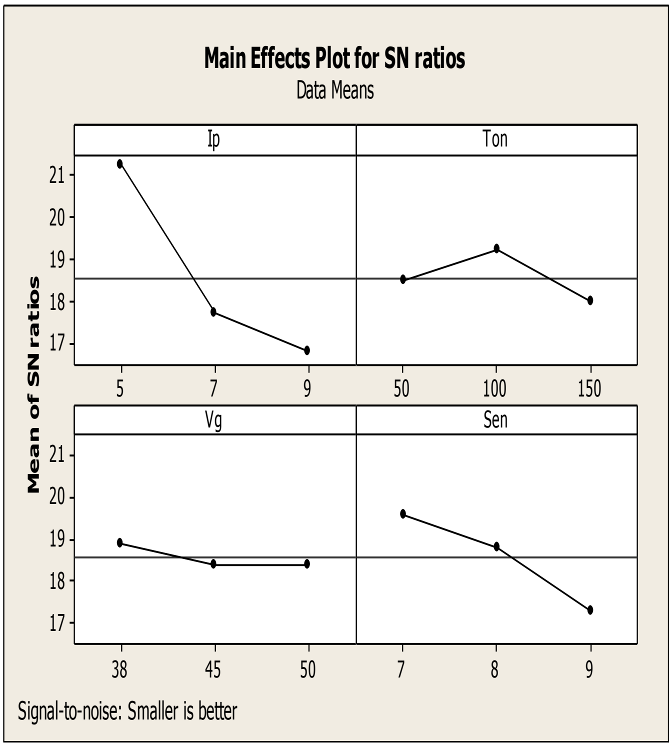

Figure 6.1.4 S/N Ratio curve for ROC with Ip,Ton,Vg,Sen

(IV) Effect of input parameters on ROC :-

From fig. 6.1.4, it is observed that in case of Peak current , it is maximum for 5 Amp and minimum for 9 Amp.. In case of Pulse-on Time, it goes on increasing from 50 to 100 µs and again decreases from 100 to 150 µs . In case of Gap voltage, from 38 it comes down to 45 Volt and then remains same for from 45 to 50 Volt. Similarly, in case of Sensitivity , it is maximum for 7 and comes down up to 8 and again decreases up to 9. For lower ROC, Peak current has maximum contribution i.e. 74.92 %. And it is followed by sensitivity and Pulse-on time. And it is less affected by Gap voltage i.e. 1.20 %.

(V) Effect of input parameters on Half Taper Angle :-

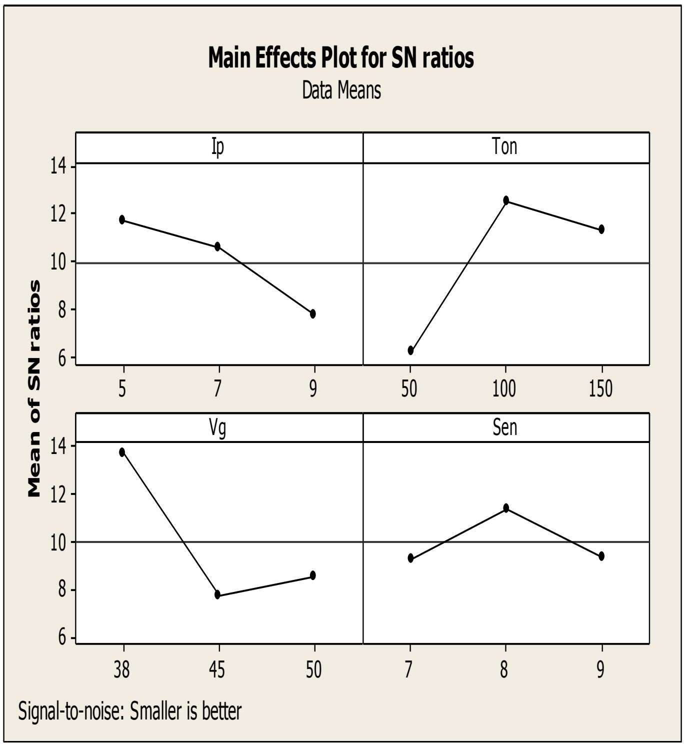

Figure 6.1.5 S/N Ratio curve for ROC with Ip,Ton,Vg,Sen

From fig. 6.1.5, it is observed that in case of Peak current , it is maximum for 5 Amp and minimum for 9 Amp.. In case of Pulse-on Time, it goes on increasing from 50 to 100 µs and again decreases from 100 to 150 µs . In case of Gap voltage, from

38 it comes down to 45 Volt and then increases up to 50 Volt. Similarly, in case of Sensitivity , it increases from 7 up to 8 and comes down up to 9. For lower T, Pulse-on time has maximum contribution i.e. 41.26 %. And it is followed by Gap voltage and Peak current. And it is less affected by sensitivity i.e. 5.17 %.

[2] Results are discussed here which are obtained from optimization by Grey Relational Method i.e. by Multi-response Optimization Technique :-

Figure 6.2.1 shows Grey Relational Grades for max. MRR, min. EWR, min. SR, min. ROC and min. Half Taper Angle.

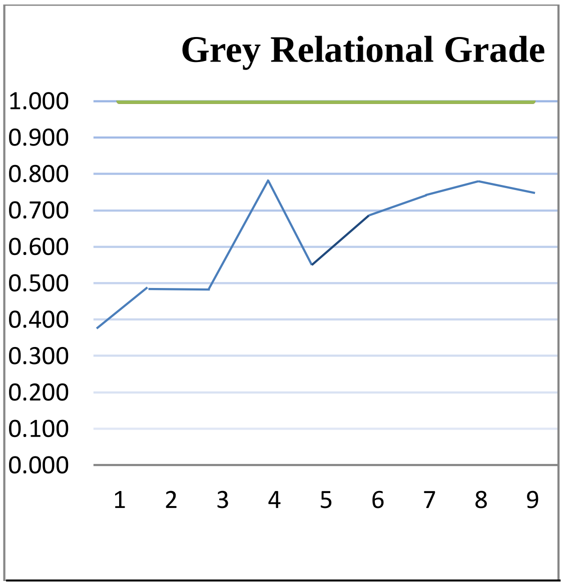

Figure 6.2.1 Grey Relational Grades for Max. MRR, Min. EWR,SR,ROC and Half Taper Angle

From above graph, it is clear that highest value of G.R.G. is at experiment no. 4. i.e. that experimental parameters obtained results which we require i.e. Higher MRR and Lower EWR, SR, ROC and Half Taper Angle.

CONCLUSION

1. The **MRR** is mainly affected by Peak curren (Ip) and Pulse-on Time. And less affected by Sensitivity.
   The **EWR** is mainly affected by Peak curren (Ip) and Sensitivity. And less affected by Pulse-on Time.
   The **SR** is mainly affected by Peak curren (Ip) and Sensitivity. And less affected by Pulse-on Time. The **ROC** is mainly affected by Peak curren (Ip) and Sensitivity. And less affected by Gap Voltage (Vg).
   The **Half Taper Angle** is mainly affected by Pulse-on Time and Gap Voltage (Vg). And less affected by Sensitivity.
2. The analysis was done by Grey Relational Grade and hence multiple response characteristics i.e. MRR, EWR, SR, ROC and Half Taper Angle were improved by using Grey Relational optimization technique.
   The optimal parameter combination determined by using this Grey Relational Analysis method was A2B1C2D3 i.e. Peak Current at 7A, Pulse-on Time at 50µs, Gap Voltage at 45V and Sensitivity at 9. Hence, Grey Relational Analysis method simplifies the optimization procedure.

REFERENCES

[1] Roselina Sallehuddin, Siti Mariyam Hj. Shamsuddin, Siti Zaiton Mohd Hashim , "Grey Relational Analysis And Its Application On Multivariate Time Series", Universiti Teknologi Malaysia, 81300.

[2] S V Subrahmanyam, M. M. M. Sarcar, "Evaluation of optimal parameters for machining with wire-cut EDM Using Grey-Taguchi Method", International Journal of Scientific and Research Publications, Vol.3, Iss.3, Mar.2013.

[3] Raghuraman S, Thiruppathi K, Panneerselvam T, Santosh S, "Optimization of EDM parameters using Taguchi method and Grey Relational Analysis for Mild Steel IS 2026",International Journal Of Innovative Research in Science, Engineering and Technology,Vol.2, Iss.7, July 2013.

[4] Anurag Joshi, "Wire-cut EDM process limitations for Tool and Die Steel ", International Journal Of Technical Research and Applications,Vol.2, Iss.1, July-Aug 2014,PP 65-68.

[5] Prabhjot Balraj Singh,Gurpreet Singh hull and Shivraj Pugga, "Study of Radial Overcut during EDM of H-13 Steel with Cryogenic cooled electrode using Taguchi Method", International Journal Of Mechanical Engg. and Robotics Research , Vol.4, Iss.1, Jan 2015,PP 33-40.

[6] Hargovind Soni,T. K. Mishra and M.K. Pradhan, "Multi-Response optimization of EDM parameters by Grey PCA method", International Journal Of Current Engg. and Technology, Vol.3, Iss.5, Dec. 2013,PP 1941-1945.

[7] B. K. Panda, Sanjeev Kumar, Priyavrat. Thareja, "Improving the Micro-hardness of OHNS Die steel by EDM process using Taguchi Approach", PEC University of Echnology, Chandigarh-160012.

[8] Dr. M.Indira Rani, Ketan, "Optimization of various machining parameters of EDM process on AISI D2 Tool Steel using Hybrid Optimization Method ", International Journal Of Application or

Innovation in Engg. and Management, Vol.3, Iss.9, Sept. 2014,PP 80-88.

[9] T Muthuramalingam, B Mohan, "Taguchi Grey Relational Based multi-response optimization of electrical process in electrical discharge machining", Indian Journal of Engg. and Materials Science, Vol.20, Dec.2013, PP 471-475.

[10] V. Jaiganesh¹ Dr.R.Raju, "Multi-Response Optimization of Wire Electrical Discharge Machining process parameters", IJAEA, Vol.1, Iss.2, 2008, PP 23-27.

AUTHOR BIBLIOGRAPHY

	**Trupti Raut** received her B.E. in Mechanical Engg. from Shivaji University and now pursuing M.E. in Mech-Prod form K.B.P. College, Satara
	**Prof. M.Y. Shinde** received her B.E and M.E. form Shivaji University. She is Assistant Professor in Mechanical Engg. department in K.B.P. College, Satara.