JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

OPTIMIZATION OF PROCESS PARAMETERS FOR WIRE EDM OF EN8 STEEL USING TAGUCHI AND TOPSIS THROUGH PYTHON PROGRAM

[1] Dr.M. Raja Roy, [2] A. Vamsi Krishna, [3] S. Anil Kumar, [4] M. Sri Varshini, [5] B. Praneeth Babu, [6] P. Bala Krishna

[1]Associate Professor, [23456]Student
[1]Department of Mechanical Engineering,
[1]Anil Neerukonda Institute of Technology and Sciences, Visakhapatnam, India

Abstract: This investigation is focused on obtaining the optimum process parameters to get minimum surface roughness and maximum metal removal rate in Wire Cut EDM. Experimentation was done using Taguchi's L16 orthogonal array and TOPSIS technique was adopted to find the optimum machining parameters. The factors of the experimental analysis consist of Pulse on time, Pulse off time, Input power and Feed rate while the responses of the model are Surface roughness and Metal removal rate. A Python program was developed to analyze and determine optimum parameter using Taguchi and TOPSIS approach.

***IndexTerms* - Taguchi, TOPSIS, ANOVA, Python, Wire EDM, optimization, material removal rate surface roughness**

I. INTRODUCTION

Electrical Discharge machining is a non-conventional thermoelectric process which erodes material from the workpiece by a series of discrete sparks between the workpiece and tool electrode immersed in a liquid di-electric medium. These electrical discharges melt and vaporize minute amounts of the work material, which are ejected and floated away by the dielectric. The sparks occurring at high frequency continuously and effectively remove the workpiece material by melting and evaporation. The dielectric acts as a de-ionizing medium between the two electrodes and its flow evacuates the re-solidified material debris from the gap assuring optimal conditions for spark generation. In wire EDM metal is cut with a special metal wire electrode that is programmed to travel along a programmed path. A wire EDM generates spark discharges between a small wire electrode (usually less than 0.5mm diameter) and a workpiece with deionized water as the dielectric medium and erodes the work piece to produce complex two- or three-dimensional shapes according to a numerical controlled path.

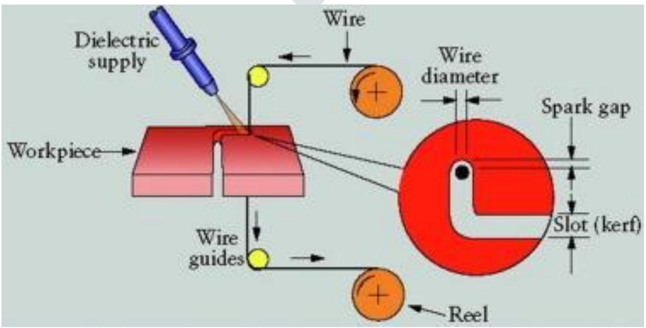

Figure 1 Schematic view of experimental set-up

The wire cut EDM uses a very thin wire 0.02 to 0.03 mm in diameter as an electrode and machines a workpiece with electrical discharge like a band saw by moving either the work piece or wire erosion of the metal utilising the phenomenon of spark discharge that is very same as in conventional EDM. The prominent feature of a moving wire is that a complicated cut out can be easily machined without using a forming electrode. Wire cut EDM machine basically consists of a machine proper composed of a workpiece contour movement control unit (NC unit or copying unit), workpiece mounting table and wire driven section for accurately moving the wire at constant tension, a machine power supply which applies electrical energy to the wire electrode and a unit which supplies a dielectric fluid with constant specific resistance.

1.1EN8 Steel

EN8, also known as 080M40, is selected as the workpiece material.EN8 is an unalloyed medium carbon steel grade with reasonable tensile strength. EN8 has good tensile strength and is often used in applications such as: shafts, gears, stressed pins, studs, bolts, keys etc.

Table 1 Chemical composition of EN8 steel

C	Si	Mn	S	P
0.36-0.44	0.10-0.40	0.60-1.00	0.005(max)	0.05(max)

II. LITERATURE REVIEW

M. Raja Roy et al.

studied the wear behavior of Titanium alloys which are widely used in medical applications due to their bio compatibility. Life of the implant material depends upon its wear resistance. Implants are generally placed inside the human body; Hence wear behavior was studied in the simulated body environment using Hank's solution. Wear tests were conducted using Pin on disc wear testing machine with ASTM G-99 standard specimens. In this study, the effect of load, speed and distance on the wear behavior were experimentally investigated. Design of experiments for conducting to wear test was determined by Taguchi experimental design method. Orthogonal arrays of Taguchi, signal-to-noise ratio and analysis of variance are employed to find the optimum parameters to minimizing the wear using MINITAB-17 software. The results showed that load is the most important parameter influencing the wear. The predicted values and experimentally measured values are good in agreement and were confirmed by validating experiments.

Ch. Maheswara Rao et al.

explored the effect of Wire EDM process parameters on machining performance characteristics of SS316 material. A series of experiments were carried out based on L27 Orthogonal Array (OA) for the Wire EDM parameters of Pulse-on-Time (TON), Pulse off-Time (TOFF), Wire Feed (WF), Wire tension (WT) and Servo Voltage (SV) taken at three different levels. The response parameters of Material Removal Rate (MRR) and Roughness (Ra) were optimized using a hybrid Taguchi method coupled with Data Envelopment Analysis based Ranking (DEAR). From the results of computed Multi Performance Rank Index (MRPI) values the optimal combinations were obtained.

Kamal Jangra et al.

The study is made to optimize the multiple machining characteristics during machining of punching die by Wire EDM using GRA and Taguchi Method. The process parameters which were investigated using mixed L18 orthogonal array are peak current (IP), pulse-on time (Ton), pulse-off time (Toff), wire speed (WS) and wire tension (WT). The performance characteristics which are optimized in this study are cutting speed (CS), surface roughness (SR), and dimensional lag (Dlag). In order to optimize three machining characteristics GRA was utilized which were investigated during rough cutting operation in D3 tool steel. After selecting process parameters and their ranges, experimental results were obtained using Taguchi's design of experiment method.

III. METHODOLOGY

3.1 Taguchi

In any experiment, the results depend to a large degree on the way in which the data were collected. In a lot of cases, full factorial experiments are conducted or-one-factor-at-a-time strategies are followed. This format cannot be implemented when there are too many factors under consideration because the number of repetitions required would be prohibitive, from a time and cost viewpoint. The latter are not able to produce credible results in case interactions among the factors exist. The most efficient method of experimental planning is DoE, which was adopted in this paper[9,11]. DoE incorporates the orthogonal arrays (OAs), developed by Taguchi, to successfully design and conduct fractional factorial experiments that can collect all the statistically significant data with the minimum possible number of repetitions. The process parameters considered and levels for each parameter

Formula to calculate S/N ratio for larger is

$$S/N = -10*\log(S(1/Y^2)/n) \qquad (1)$$

Table 2 Process parameters and levels

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Pulse ON Time(µs)	110	115	120	125
Pulse OFF Time(µs)	45	50	55	60
Peak Current(A)	200	210	220	230
Wire Feed(m/min)	2	3	4	5

3.2 TOPSIS

TOPSIS- Techniques for order preferences by similarity to ideal solution.

Taguchi can give results only with one response parameter so the TOPSIS method has been applied to overcome the multi-response into a single response. The two response parameters Material removal rate and Surface roughness are converted into single parameters using the TOPSIS formulas. The steps followed for the TOPSIS in the present research work are given below.

Step 1 Decision matrix is normalized by using the following equation:

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}} \qquad (2)$$

Where i = 1…. m and j = 1 ….n.

a_{ij} represents the actual value of the th value of the experimental run and represents the corresponding normalised value.

Step 2 Weight for each response is calculated.

Step 3 The weighted normalized decision matrix is then calculated by multiplying the normalized decision matrix by its associated weights. The weighted normalized decision matrix is formed as

$$V_{ij} = W_{ij} \times r_{ij} \qquad (3)$$

Where i = 1 …m and j = 1 …n represents the weight of the attribute or criteria.

Step 4 Positive ideal solution (PIS) and negative ideal solution (NIS) are determined as follows:

$$V^{+} = (V_1^{+}, V_2^{+}, \dots \dots, V_n^{+}) \text{ maximum values}$$
$$V^{-} = (V_1^{-}, V_2^{-}, \dots \dots, V_n^{-}) \text{ minimum values}$$

Step 5 The separation of each alternative from positive ideal solution (PIS) and negative ideal solution (NIS) is calculated as

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^{+}\right)^2} \qquad (4)$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^{-}\right)^2} \qquad (5)$$

Where i = 1, 2, ….m

Step 6 The closeness coefficient of each alternative (CC_i) is calculated as

$$CC_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}} \qquad (6)$$

IV. SOFTWARE APPLICATION DEVELOPED FOR TOPSIS AND TAGUCHI

A dedicated program is developed using python language to convert the multi-response problem to single response problem based on TOPSIS. Optimisation parameters are also obtained through the program and main effect plots are drawn as output of the program. The key feature of the program is collecting the data from the excel file and sending the solution to the excel file. This program can avoid the use of multiple software's like excel for TOPSIS and minitab for Taguchi. This software program directly gives the result of TOPSIS followed by Taguchi optimisation.

Libraries used in the python code are matplotlib, openpyxl and math library.

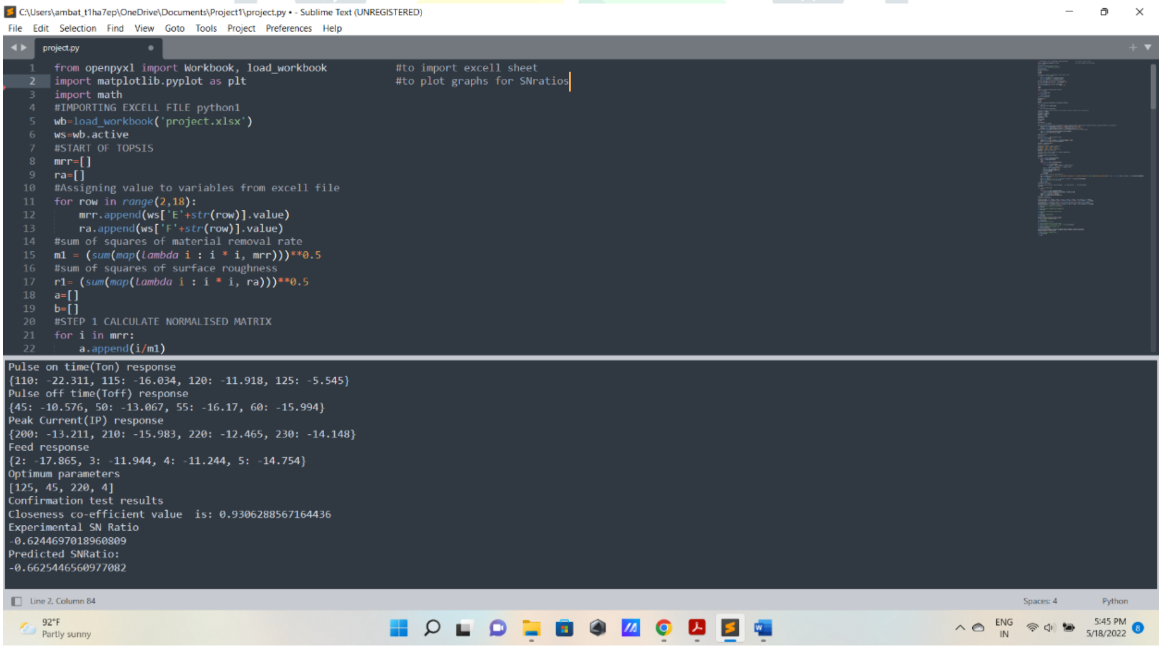

Figure 2 Python code snippet

V. EXPERIMENTATION

Figure 3 Wire EDM equipment

The experimental work was done by Taguchi design of experiments. Machining is done on EN8 work piece by CNC Wire Electrical Discharge Machining as per the DOE table as shown in table 3. Metal removal rate and surface roughness are measured during the experiments. Analysis of results was done using TOPSIS and ANOVA.

Table 3 DoE Table

Expt	T_{on}(μs)	T_{off}(μs)	IP(A)	FEED (m/min)
1	110	45	200	2
2	110	50	210	3
3	110	55	220	4
4	110	60	230	5
5	115	45	210	4
6	115	50	200	5
7	115	55	230	2
8	115	60	220	3
9	120	45	220	5
10	120	50	230	4
11	120	55	200	3
12	120	60	210	2
13	125	45	230	3
14	125	50	220	2
15	125	55	210	5
16	125	60	200	4

The constant parameters while machining is in table 4

Table 4 Constant parameters

Peak Voltage (VP)	Flushing Pressure (WP)	Wire Tension (WT)	Spark gap Voltage (SV)	Servo Feed rate (SF)
2V	1 Kg/cm^2	8N	20V	2100 mm/min

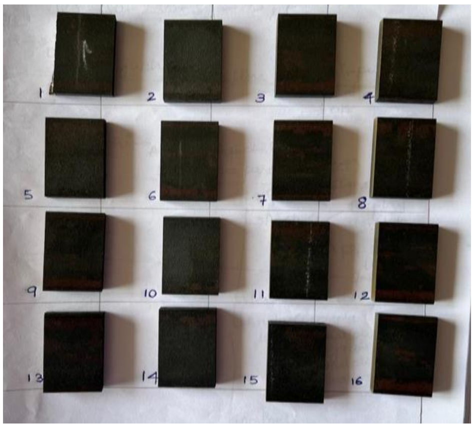

Figure 4 Work pieces after machining

Before every cut the input parameters are varied using the input keyboard. A brass wire of 0.27mm diameter is fed towards the workpiece with the help of NC controllers. The time taken for each cut is noted for the given input. One of the two response parameters, material removal rate is calculated using the formula

$$MRR = \frac{W*T*L}{Time(in\ min)} \qquad (7)$$

Where

L is length of workpiece =32mm

T is thickness of workpiece =6mm

W is width of cut = 0.27mm

Surface roughness is measured using the Surftest SJ-210- Series 178-Portable Surface Roughness Tester.

Figure 5 Surftest SJ-210- Series 178 Portable Surface Roughness Tester

The values of material removal rate and surface roughness are in the below table

Table 5 Measured MRR and Ra

Expt	T_{on}(µs)	T_{off}(µs)	IP	FEED	MRR mm^3/min	Ra (µm)
1	110	45	200	2	3.585536	3.672
2	110	50	210	3	3.257184	3.398
3	110	55	220	4	3.262109	3.423
4	110	60	230	5	3.043627	3.65
5	115	45	210	4	4.424467	3.812
6	115	50	200	5	4.114286	3.552
7	115	55	230	2	3.646424	3.86
8	115	60	220	3	4.443429	3.628
9	120	45	220	5	6.2208	3.598
10	120	50	230	4	5.960766	3.845

11	120	55	200	3	4.443429	3.523
12	120	60	210	2	3.62208	3.618
13	125	45	230	3	9.82	3.447
14	125	50	220	2	5.265574	3.098
15	125	55	210	5	5.201338	3.323
16	125	60	200	4	7.886857	3.324

VI. RESULTS AND DISCUSSION

6.1 TOPSIS results

After applying TOPSIS method to the output parameters i. e surface roughness and material removal rate, we get closeness coefficient (CC_i) values

Table 6 Closeness co-efficient values

T_{on} (μs)	T_{off} (μs)	IP (A)	FEED m/min	CC_i
110	45	200	2	0.088109
110	50	210	3	0.097366
110	55	220	4	0.093259
110	60	230	5	0.043122
115	45	210	4	0.201006
115	50	200	5	0.168227
115	55	230	2	0.087661
115	60	220	3	0.209588
120	45	220	5	0.465615
120	50	230	4	0.421046
120	55	200	3	0.215212
120	60	210	2	0.097992
125	45	230	3	0.930122
125	50	220	2	0.353144
125	55	210	5	0.33154
125	60	200	4	0.714421

6.2 Taguchi results analysis

Analysis of experiments was done using the Taguchi method and S/N ratios are obtained for single response CCi obtained from multiple responses by TOPSIS using Python code were shown in the following table.

Table 7 S/n Ratio for closeness coefficient

Ton (μs)	Toff (μs)	IP (V)	FEED m/min	CCi	SNRA	Fits SNRA
110	45	200	2	0.088109	-21.0996	-22.1074
110	50	210	3	0.097366	-20.2319	-21.4494
110	55	220	4	0.093259	-20.6062	-20.3344
110	60	230	5	0.043122	-27.306	-25.3514
115	45	210	4	0.201006	-13.9358	-11.9814
115	50	200	5	0.168227	-15.4821	-15.2104
115	55	230	2	0.087661	-21.1438	-22.3614
115	60	220	3	0.209588	-13.5727	-14.5814
120	45	220	5	0.465615	-6.63947	-7.85736
120	50	230	4	0.421046	-7.51342	-8.52136
120	55	200	3	0.215212	-13.3427	-11.3874
120	60	210	2	0.097992	-20.1762	-19.9044
125	45	230	3	0.930122	-0.6292	-0.65736
125	50	220	2	0.353144	-9.04095	-7.08636
125	55	210	5	0.33154	-9.58929	-10.5964
125	60	200	4	0.714421	-4.92092	-4.13836

From the SN Ratios, the response values for each input parameter were found out.

Table 8 Response table for signal to noise ratio

Level	T_{on}	T_{off}	IP	FEED
1	-22.311	-10.576	-13.211	-17.865
2	-16.034	-13.067	-15.983	-11.944
3	-11.918	-16.17	-12.465	-11.244
4	-5.545	-15.994	-.14.148	-14.754

6.3 ANOVA

ANOVA was used to determine the design parameters significantly influencing the mass loss (response). Analysis of variance (ANOVA) results were shown in Table-6. This analysis was evaluated for a confidence level of 95%, that is for significance level of α=0.05. It can be observed from the results obtained, that T_{on} was the most significant parameter having the highest statistical contribution (70.648%) followed by Feed (12.952%) followed by T_{off} (10.085%) and IP (3.283%). Contribution for each source parameter is calculated as follow.

$$\% \, Contribution = \frac{seq \, SS \, of \, each \, parameter}{Total \, of \, each \, parameter} * 100 \qquad (8)$$

Table 9 Analysis of variance for S/N Ratio

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
T_{on}	3	596.07	596.07	198.36	23.31	0.014	70.648
T_{off}	3	85.09	85.09	28.362	333	0.175	10.085
IP	3	27.70	27.70	9.233	1.08	0.475	3.283
FEED	3	109.28	109.28	36.427	4.21	0.132	12.952
RESIDUAL	3	25.57	25.57	8.524			3.030
TOTAL	15	843.71					100

6.4 Main Effect Plot for SN Ratio

Use in conjunction with an analysis of variance and design of experiments to examine differences among level means for one or more factors. A main effect is present when different levels of factors affect the response differently. A main effects plot graphs the response mean for the each factor level connected by a line.

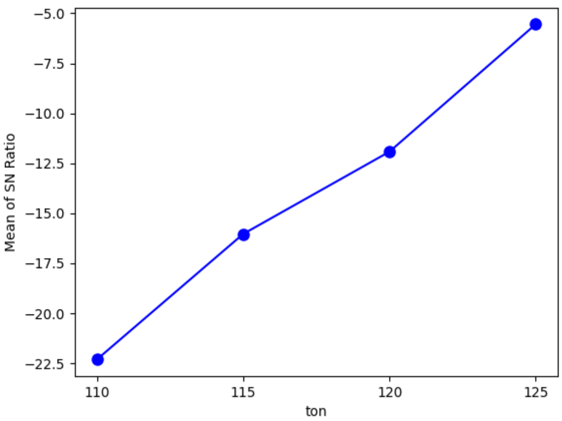

Figure 6 Ton effects plot

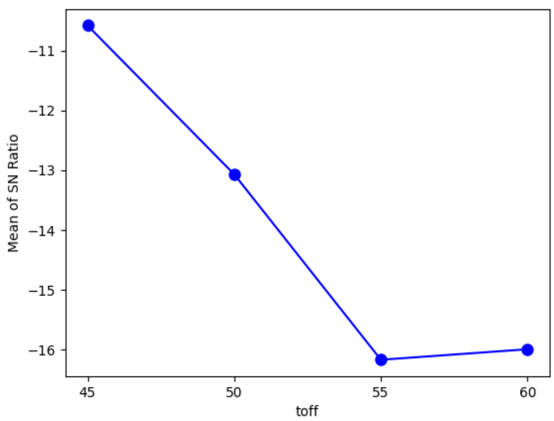

Figure 7 Toff effects plot

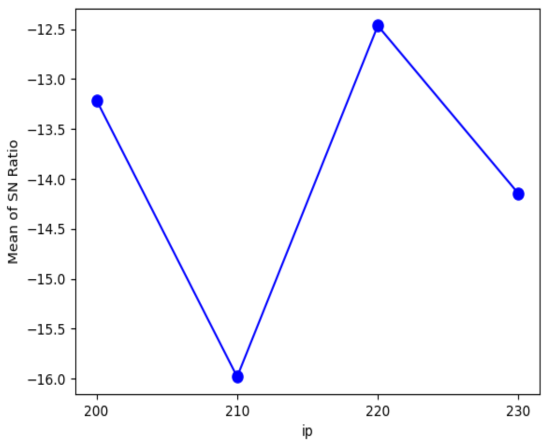

Figure 8 Input power effect plot

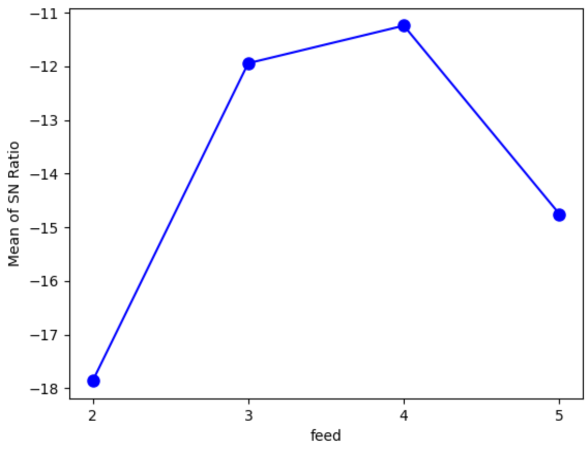

Figure 9 Feed rate efffects plot

6.5 Optimum factors based on mean effect plot

Based on the graph, optimum parameter values are found out for larger Sn Ratio value as the better.

Table 10 Optimum parameters based on mean effect plot

S.NO	Factor	Level	Corresponding Value	Mean of S/N dB
1	TON	4	125µs	-5.545
2	TOFF	1	45 µs	-10.576
3	IP	3	220A	-12.465
4	FEED	3	4m/min	-11.244

6.6 Predicted S/N ratio

S/N ratio is predicted by using the equation

$$S/N_{Predict} = S/N_{TotalMean} + \Sigma\,(S/N_{meanOptfactor} - S/N_{totalmean}) \qquad (9)$$

Predicted S/N ratio =-0.662Db

6.7 Confirmation Test

The conformation experiment is very important in parameter design. The purpose of conformation experiment in the present work was to validate the optimum factors TON4, TOFF1, IP3 & Feed3. .The average of three experimental results of the confirmation experiment was listed in Table

Table 11 Result of confirmation test

T_{on} (µs)	T_{off} (µs)	IP (A)	FEED (m/min)	CC_i	s/n Ratio	predicted s/n ratio	% Of Error
125	45	220	4	0.9306	-0.624	-0.662	5.74

VII. CONCLUSIONS

This study has presented the application of multi-response optimization using TOPSIS and Taguchi approach for maximizing the Material removal rate and minimizing surface roughness during the Wire EDM. A program is developed using python and following conclusions were drawn from the experimental and predicted results.

1. Optimum parameters for maximizing the Material removal rate and minimizing surface roughness were obtained i.e., Pulse on time 125µs, Pulse off time 50µs, Wire Feed 4m/min and Peak Current 220A.

2. ANOVA results of the optimum parameters shows that, Pulse on time has high contribution with 70.648% followed by Feed (12.952%) followed by T_{off} (10.085%) and IP (3.283%).

3. Predicted S/N Ratio has been obtained as -0.662dB at optimum parameters.

4. Confirmation experiment was conducted at optimum parameters and S/N ratio was obtained as -0.624dB. The predicted values and experimentally measured values are good in agreement with 5.740% error.

REFERENCES

[1] M.RajaRoy et al "Multiple Optimization of Wire EDM Machining Parameters Using Grey Based Taguchi Method for Material HCHCR.International Of Modern Engineering Research" ISSN: 2249–6645 Vol. 4 ,Iss. 2 Feb. 2014.

[2] M.RajaRoy et al "Optimisation of Material Removal Rate and Surface Roughness of MoS2 Reinforced Aluminum Metal Matrix Composite in Wire-EDM Process." International Journal of Engineering Development and Research Volume 6, Issue 4 | ISSN: 2321-9939.

[3] G.Rajyalakshmi et al ``Optimization of Process parameters of Wire Electrical Discharge Machining on Inconel 825 using Grey Relational Analysis Coupled with Principle Component Analysis." International Journal of Applied Engineering Research ISSN 0973-4562 Volume 8, Number 11.

[4] Ch.Maheswara Rao "EDM Process parameters in Machining SS316 using DEAR method.Journal of Recent Trends in Mechanics" e-ISSN: 2582-3213 Volume-5, Issue-3 (September-December, 2020).

[5] M. Geeta Rani et al "Experimental Investigation on Optimization of the Controlling Factors for Machining Al 6061/MoS2 Metal Matrix Composites with Wire EDM." International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 22.

[6] M.V.N. Srujan Manohar et al "Optimization of Machining Parameters for AISI 316L And 317L Austenitic Stainless Steels using Eco-Cut Wire-EDM Technique." International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-9, Issue-2.

[7] Lokeswara Rao T et al "Optimization of WEDM Process Parameters on Titanium Alloy Using Taguchi Method."International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 4, Jul. - Aug. 2013 pp-2281-2286.

[8] Pawan Kumar et al "Optimization of process parameters for WEDM of Inconel 825 using grey relational analysis." Decision Science Letters 7 (2018) 405–416.

[9] Kamal Jangra "Simultaneous optimization of material removal rate and surface roughness for WEDM of WCCo composite using grey relational analysis along with Taguchi method." International Journal of Industrial Engineering Computations 2 (2011) 479–490

[10] S Sivakiran "Effect of Process Parameters on Metal Removal Rate In Wire Electrical Discharge Machining Of En31 Steel." International Journal of Engineering Research and Applications Vol. 2, Issue 6, November- December 2012

[11] Mohd Sazali Md Said" Comparison between Taguchi Method and Response Surface Methodology (RSM) In Optimising Machining Condition" International Conference on Robust Quality Engineering

[12] Kamal Jangra "Optimization OF Multiple-Machining Characteristics in Wire EDM OF Punching DIE using GREY RELATIONAL Analysis." International Conference on Robust Quality Engineering vol 69 August 2010.

[13] M. Durairaj et al. "Analysis of Process Parameters in Wire EDM with Stainless Steel using Single Objective Taguchi Method and Multi Objective Grey Relational Grade 64" (2013) 868 – 877.

[14] Maheswara Rao Ch et al "Optimization of Wire EDM Process Parameters using a Composite Method of AHP based TOPSIS" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181.

[15] S.Vignesh et al "Parameter Optimization of Wire EDM in a Range of Thickness for EN8 Die Steel"International journal for trends in engineering & technology volume 5 issue 2 – May 2015 - ISSN: 2349 - 9303