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Experimental investigation intooptimize process Parameters electro discharge machining for A2 steel

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ABSTRACT- In this study electro discharge process parameters are optimized by using Taguchi method. Process parameters considered for the study are pulse on time, voltage current. A2 steel is high hardness and tensile strength alloy which is mostly used in gauges, forming dies, stamping dies and tooling application that where high degree and dimensional accuracy is required. A2 steel plate of rectangular shape has been used for machining operation. Performance of electro discharge machine with a copper electrode has been measured by surface roughness and material removal rate. In Taguchi method L9 orthogonal array has been selected. The analysis of variance (ANOVA) has been used to determine effect of each parameter on surface roughness (SR) and material removal rate (MRR).

Keywords- Taguchi Method, Signal to Noise(S/N) Ratio,EDM, Process Parameters, MRR, SR.

I. INTRODUCTION

Electrical Discharge Machining (EDM) is a thermo-electrical process in which material is eroded by a series of sparks generated between the workpiece and electrode tool. Workpiece and the electrode are immersed in a dielectric fluid. In EDM, dielectric fluid acts as a coolant and to maintain a constant gap between the workpiece and electrode. During machining, there will be no contact between workpiece and the electrode, thus materials of any hardness can be cut as long as they can conduct electricity, physical pressure imparted on the workpiece is low and the amount of clamping pressure required to hold the workpiece is also minimized.

In recent times, industries which manufacture tools, dies, molds and metal-workings, are in need of materials which have high resistance, high wear and tear, hardness, strength and toughness. Hence development of new materials like titanium, inconel, ceramics, zirconium, stainless steel, carbides and many other high strength temperature resistant alloys are widely used in automobile, aerospace, medical, defence, tool and die manufacturing industries. For such materials, machining by conventional process is difficult and sometimes impossible. Thus, non-conventional processes are applied instead of traditional methods for extremely hard and brittle materials. One such non-conventional process is electrical discharge machining (EDM). Manufacturing process is modern manufacturing scenario. The process is mainly used in mould and dies making, aerospace and automotive industries. Higher productivity with minimum cost is motive of almost all the industries. With increasing demand for quality product as well as for higher productivity, EDM need to be performed more efficiently. Thus one of the most interesting and investigating areas is the modeling and optimization ofprocess parameters to achieve a high quality product with the reduction of manufacturing cost.

II. EXPERIMENTATION

A. Methodology of Experiment

There are several optimization techniques to develop product, process or operation. Various techniques can be applied to optimize WEDM process. Sometimes different techniques are required integrate to get statistically significant results, which can lead to better conclusions and recommendations. Some extensively used methods in developing a process or a product are Build Test Fix (BTF), Design of Experiment (DOE) and One Variable at a Time (OVAT), BTF is very primitive and unorganized approach. It is iterative method of developing a process focused on improvement from last experiment. DOE is highly efficient

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method of investigating the effect of parameters as it varies multiple parameters at once. As more parameters are investigated, more number of new combinations are required. DOE cannot control individual parameters and more relies on statistical data. In one variable at a time (OVAT) approach, variation is done with one variable at a time and other parameters are kept constant until the effect of one parameter is studied.

It is highly precise method to study effect of each parameter at different levels. Pulse on time (T-on), Pulse off time (T-off) and Current were identified as most predominant parameters affecting the WEDM. Based on the observation, Taguchi method has been used to optimize the process parameters. OVAT analysis has been conducted to find out effective range of parameters for optimization study. L9 orthogonal array (OA) has been selected from available designs. Standard notation for OA is given below

OA = Ln(Xm)

Where n= number of experiments, X= number of levels and m= number of parameters under study. From available designs for 3 levels 3 parameters, OA with least number of experiment required to conduct (L9) has been selected. ANOVA has been conducted to find out contribution of each parameter in the output. Minitab 19 software has been used for analysis.

B. Experimental Machine Selection

Table 1 states the specification of the EDM used in this study. All the experiments were conducted at DIP Industries, C-165 MIDC Waluj, Aurangabad, M.S, India

Make and Model	**ECO-32S**
Work Table Size	650 x 400 mm
Working Travel	200 mm
Max. Work piece Weight	900 kg
Machine Dimensions	1455x1680x2125
Machine Weight	2000 kg

Table 1EDM Machine Specification.

Figure.2.1 Setup Electro discharge Machine

C. Selection of material

A2 Steel material is used as work piece in this research work. Size available in round, flat and square shape. The application of this material mainly used in mould and dies making, aerospace and automotive industries Literature study indicates that research can be conducted to evaluate effect of process parameters like pulse on time, current and voltage of EDM on MMR and TWR.

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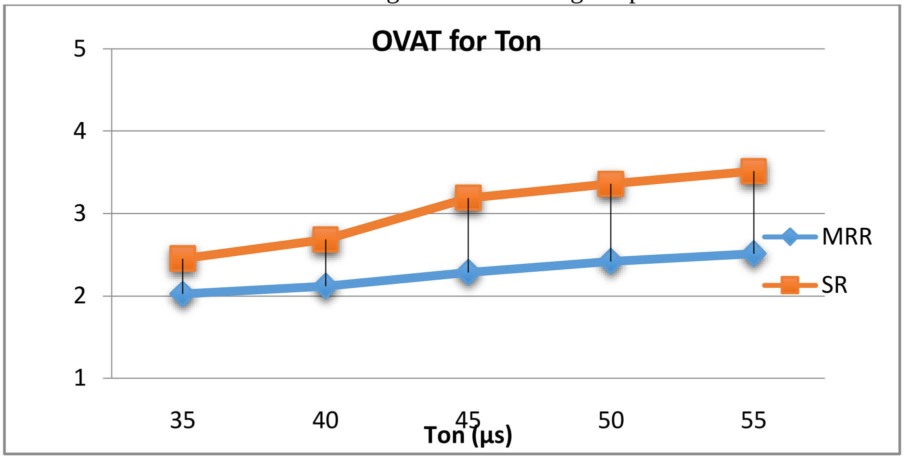
C	Si	Mn	P	S	Cr	Mo	V
0.95-1.05	0.10-0.40	0.40-0.80	0.030max	0.030max	4.80-5.50	0.90-1.20	0.15-0.35

Fig.1 Chemical composition

Fig.2 A2 Steel

D. OVAT for Pulse on Time(T-on)

Variation in material removal rate andsurface roughness with change in pulse on time is shown in Figure 2.3.

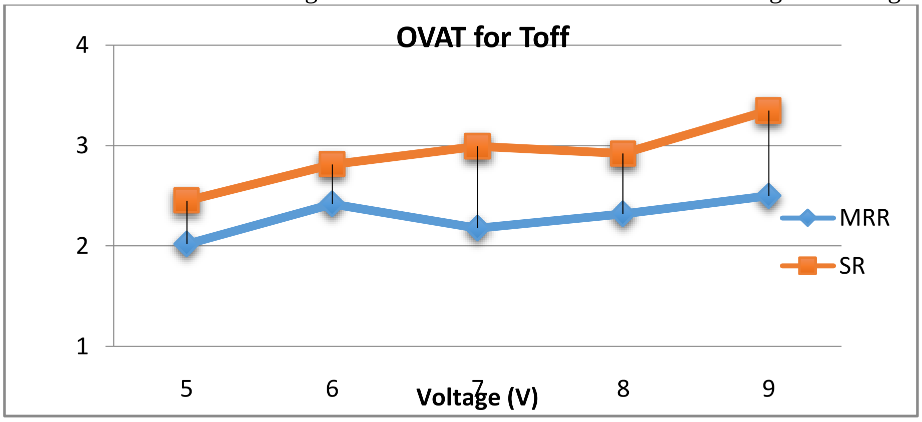


Graph 2.3 OVAT for T-on.

Voltage time and current kept constant and pulse on time varied from 35 to 55 µsec. From the fig 2.3, it has been observed that as pulse on time increases from 35 to 40 µsec, the surface roughness and material removal rate increases drastically from 35 to 55 µse. also has been observed that, the rate of change of surface roughness and material removal rate is higher in the region of pulse on time of 40 to 50 µse hence this level of factor has been selected.

E. OVAT for Voltage (V)

Figure 2.4 shows variation in surface roughness and material removal rate with change in Voltage



Graph 2.4 OVAT for Voltage.

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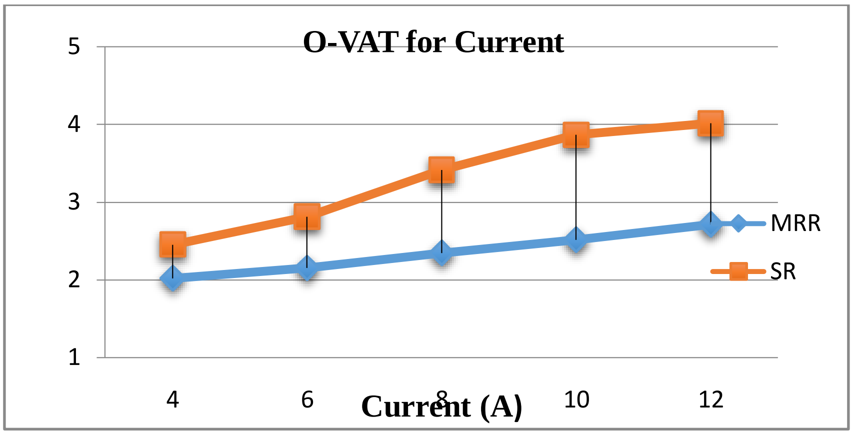
It has been observed that, as Voltage increases, surface roughness and material removal rate increases at certain level. The rate of change of surface roughness and material removal rate is higher in the region of Voltage is 5 to 7V hence this level of factor has been selected.

D. OVAT for Current

Figure 2.4 shows variation in surface roughness and material removal rate with change in Current



Graph 2.5 O-VAT for Current.

It has been observed that, as Current is increases, surface roughness and material removal rate increases. The rate of change of surface roughness and material removal rate is higher in the region of Current is 6 to 8 A. hence this level of factor has been selected.

Three levels for each parameter has been selected for optimization. Selecting more than 3 levels would have needed more experiments to be conducted. Selecting less than 3 levels is not justified for investigation of effect of parameters for 1st time. Table 3 shows three levels of input parameters selected for optimization study.

G. Levels of Input Parameters

Sr. No	Level 1	Level 2	Level 3
Ton(μs)	40	45	50
Voltage (V)	5	6	7
Ip (A)	6	8	10

Table 3. Levels of Input Parameters

III. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters pulse on time, voltage time and current on output surface roughness and material removal rate, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 19 statistical software has been used. Modeling of surface roughness and material removal rate has been done. ANOVA has been conducted to find out effect of each parameter on the surface roughness, material removal rate and linear regression model has been established to predict the values of surface roughness and material removal rate.

A. Experimental Result

Table 4 shows the L9 orthogonal array with measurement of material removal rate for runs one to nine. It also shows S/N ratio for all nine experiments.

Experiments	**Inputs Factors**			**Output Responses**	
Trial No.	**Ton**	**voltage**	**Ip**	**MRR**	**S/N Ratio**
1	40	5	6	1.992	5.98579
2	40	6	8	2.347	7.41026

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3	40	7	10	2.579	8.22903
4	45	5	8	2.181	6.77311
5	45	6	10	2.724	8.70414
6	45	7	6	2.257	7.07063
7	50	5	10	2.674	8.54323
8	50	6	6	2.478	7.88203
9	50	7	8	2.678	8.55621

Table 4 L9 orthogonal array with response characteristic.

The S/N ratio values are calculated with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

B. Main Effects of MRR

Figure 3.1 shows the main effects plot from S/N ratios.

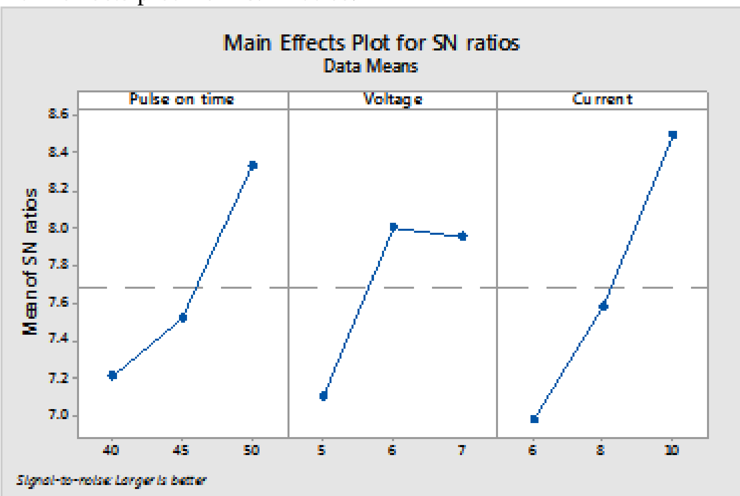

Figure.3.1 Main Effects Plot for S/N Ratio

From main effects plot for S/N ratio, parametric effect on response characteristic i.e. material removal rate can be understood. Pulse on time 28µsec at level 1, Pulse off time 7µsec at level 1, Current 6 A at level 3 gives the highest signal to noise ratio values. The levels at which highest S/N ratio obtained from S/N ratio plot taken as optimum levels setting for machine parameters.

C. ANOVA Result

ANOVA, the ratio between the variance of the cutting parameter and the error variance is called Fisher's ratio (F). It is used to determine whether the parameter has a significant effect on the quality characteristic by comparing the F test value of the parameter with the standard F table value at the P significance level. If the F test value is greater than P test the cutting parameter is considered significant. Relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test). ANOVA table shown the result of the ANOVA analysis. ANOVA analysis makes it possible to observe that the value of P is less than 0.05 in the three parametric sources. It is therefore clear that pulse on time, pulse off time and current of the material have an influence on the HCHCR Steel. The last column of cumulative ANOVA shown the percentage of each factor in the total variance that indicates the degree of impact on the outcome. Table 6 shows results obtained from analysis of variance

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**	**% Contribution**
Pulse on time	2	0.148612	0.074306	33.95	0.029	28.44

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Voltage	2	0.104324	0.052162	23.84	0.040	19.96
Current	2	0.265154	0.132577	60.58	0.016	50.75
Error	2	0.004377	0.002188			
Total	8	0.522466				

Table 6 ANOVA Result.

It shows that the pulse on time (28.44%), the voltage (19.96%) and the Current (50.57%) have major influence on the material removal rate. Contribution of current (50.57%) is highest among all three parameters hence it is most dominating parameter while pulse off time is least affecting parameter.

D. Development of Regression Model for material removal rate

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for material removal rate have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of material removal rate correlates with each other.

Regression Equation –

$$SR = -0.434 + 0.03040 \text{ Pulse on time} + 0.1112 \text{ Voltage} + 0.1042 \text{ Current}$$

Table number 7 gives comparison between experimentally measured and predicted material removal rate by developed mathematical equation

Sr. No.	**Experimental value**	**Predicted value**	**Error %**
1	1.992	1.967	1.27
2	2.347	2.287	2.62
3	2.579	2.608	1.11
4	2.181	2.327	6.27
5	2.724	2.648	2.87
6	2.257	2.343	3.67
7	2.674	2.688	4.58
8	2.478	2.383	3.98
9	2.678	2.703	5.68

Table 7 Experimental and Predicted Values of MRR

Difference between surface roughness values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid. Figure 3.2 shows the graphical representation of experimental and values calculated using regression equation.

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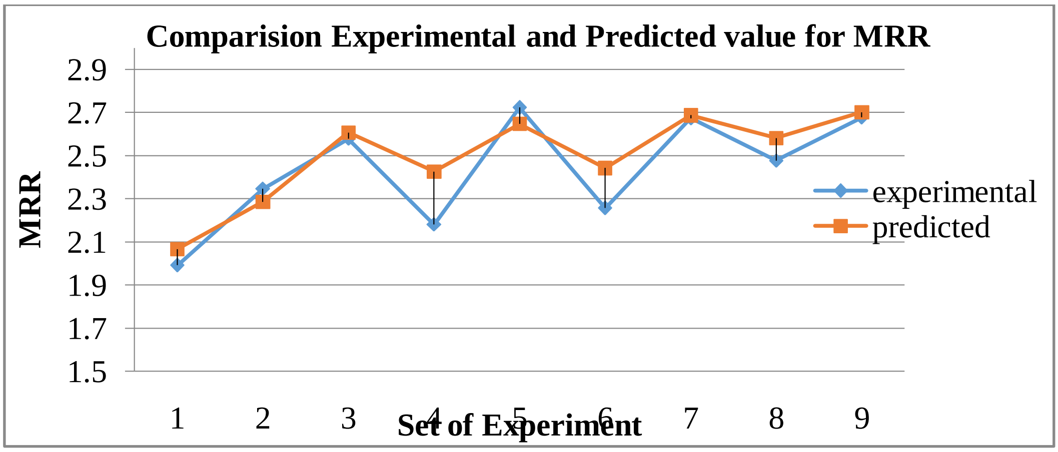

Figure 3.2 Comparison between Experimental and Predicted value of Material removal rate.

E. Confirmation Experiment Result

Table 8 shows the difference between value of material removal rate of confirmation experiment and value predicted from regression model developed.

Parameter	Model value	Experimental value	Error %
Material Removal Rate	2.795	2.735	2.36

Table 8 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the MRR value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 3.04%. This indicates that the experimental value correlates to the estimated value.

F. Experimental Result

Table 4 shows the L9 orthogonal array with measurement of surface roughness for runs one to nine. It also shows S/N ratio for all nine experiments.

Experiments	**Inputs Factors**			**Output Responses**	
Trial No.	**Pulse on time (µs)**	**Voltage(V)**	**Current (A)**	**SR(Ra) (µm)**	**S/N Ratio**
1	40	5	6	3.380	-10.5783
2	40	6	8	2.615	-8.3494
3	40	7	10	2.499	-7.9553
4	45	5	8	2.860	-9.1273
5	45	6	10	3.023	-9.6088
6	45	7	6	2.907	-9.2689
7	50	5	10	3.240	-10.2109
8	50	6	6	3.477	-10.8241
9	50	7	8	2.531	-8.0658

Table 9. L9 orthogonal array with response characteristic.

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The S/N ratio values are calculated with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

G. Main Effects of SR

Figure 3.3 shows the main effects plot from S/N ratios.

From main effects plot for S/N ratio, parametric effect on response characteristic i.e. SR can be understood. Pulse on time 40µsec at level 1, voltage 7V at level 3, Current 2 A at level 2 gives the highest signal to noise ratio values. The levels at which highest S/N ratio obtained from S/N ratio plot taken as optimum levels setting for machine parameters.

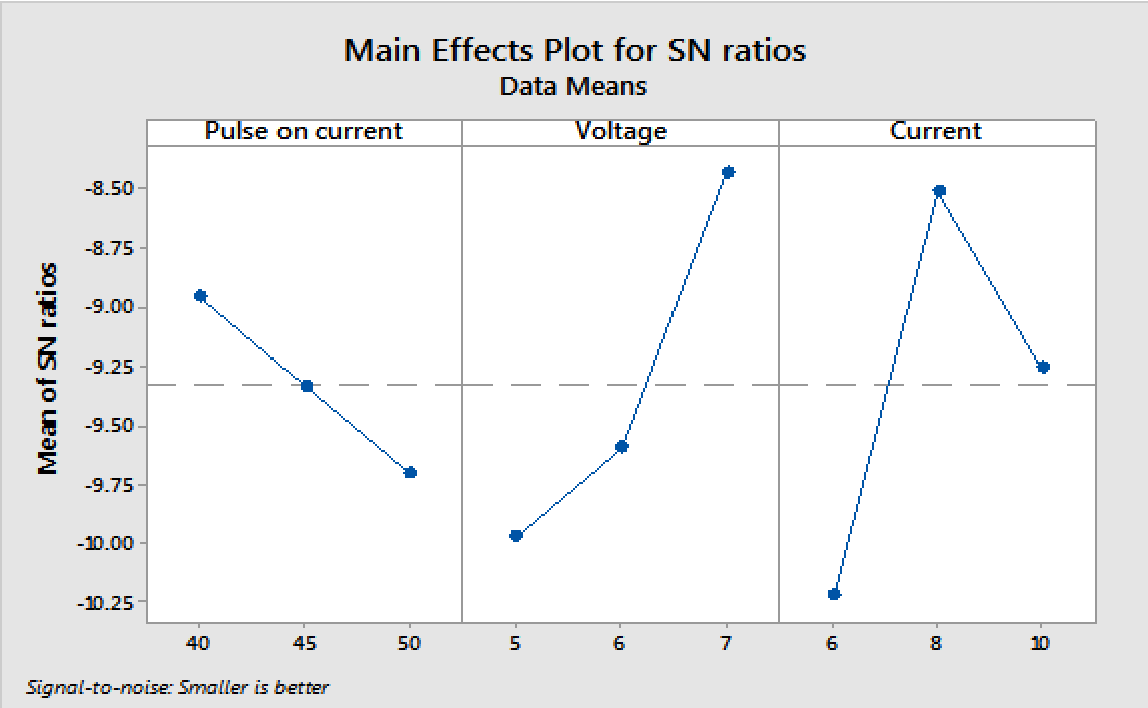

Figure.3.3 Main Effects Plot for S/N Ratio

H. ANOVA Result

ANOVA, the ratio between the variance of the cutting parameter and the error variance is called Fisher's ratio (F). It is used to determine whether the parameter has a significant effect on the quality characteristic by comparing the F test value of the parameter with the standard F table value at the P significance level. If the F test value is greater than P test the cutting parameter is considered significant. Relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test). ANOVA table shown the result of the ANOVA analysis. ANOVA analysis makes it possible to observe that the value of P is less than 0.05 in the three parametric sources. It is therefore clear that pulse on time, pulse off time and current of the SR have an influence on the HCHCR Steel. The last column of cumulative ANOVA shown the percentage of each factor in the total variance that indicates the degree of impact on the outcome. Table 10 shows results obtained from analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Pulse on time	2	0.09621	0.048105	19.39	0.049	9.13
Voltage	2	0.43353	0.216764	87.36	0.011	41.16

Current	2	0.51846	0.259228	104.47	0.009	49.22
Error	2	0.00496	0.002481			
Total	8	1.05316				

Table 10 ANOVA Result.

It shows that the pulse on time (9.13%), the voltage (41.16%) and the Current (49.22%) have major influence on the Surface roughness. Contribution of current (49.22%) is highest among all three parameters hence it is most dominating parameter while pulse on time is least affecting parameter.

I. Development of Regression Model for Surface roughness

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for surface roughness have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of surface roughness correlates with each other.

Regression Equation –

SR = 4.03 + 0.0251 Pulse on current - 0.257 Voltage - 0.0835 Current

Table number 7 gives comparison between experimentally measured and predicted surface roughness by developed mathematical equation.

Sr. No.	**Experimental value**	**Predicted value**	**Error %**
1	3.380	3.248	4.06
2	2.615	2.824	7.40
3	2.499	2.400	4.12
4	2.860	3.206	9.79
5	3.023	2.782	8.66
6	2.907	2.859	1.67
7	3.240	3.165	3.26
8	3.477	3.242	7.24
9	2.531	2.801	9.63

Table 7 Experimental and Predicted Values of SR

Difference between surface roughness values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid. Figure 3.4 shows the graphical representation of experimental and values calculated using regression equation.

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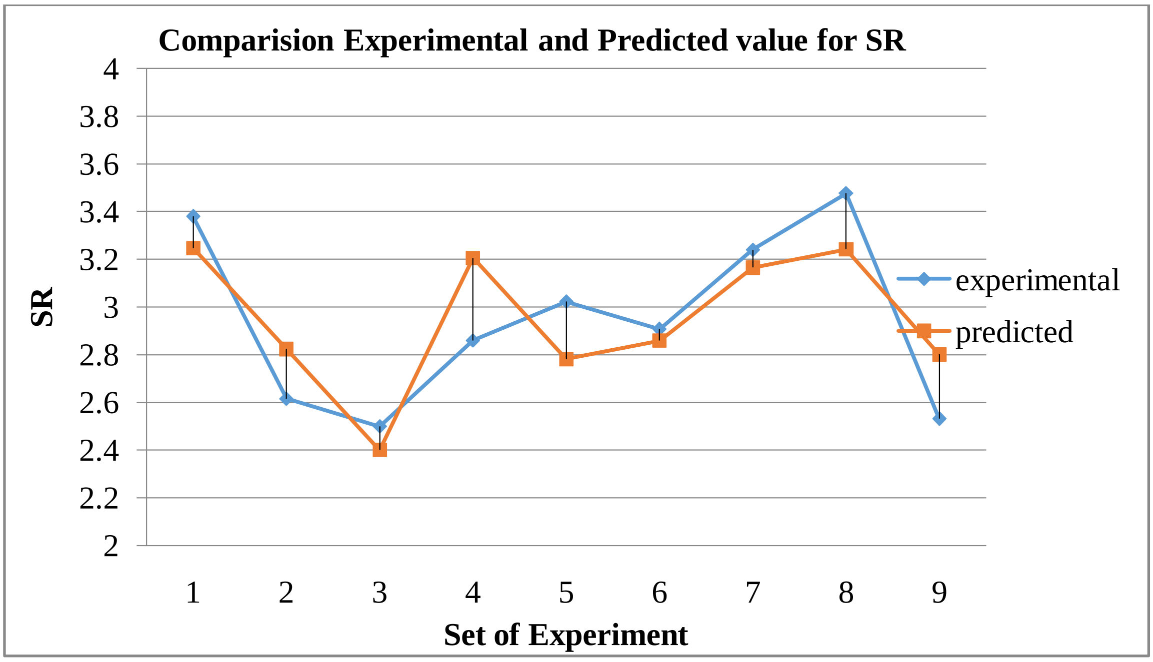

Figure 3.4 Comparison between Experimental and Predicted value of SR.

J. Confirmation Experiment Result

Table 8 shows the difference between value of surface roughness of confirmation experiment and value predicted from regression model developed.

Parameter	Model value	Experimental value	Error %
SR	2.799	2.308	2.36

Table 8 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the surface value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 3.04%. This indicates that the experimental value correlates to the estimated value.

K. Conclusions

In this study the influence of process parameters such as pulse on time, pulse off time and current and their optimization for A2 Steel has been studied by using Taguchi Method. Following conclusions are drawn.

1) The optimal solution obtained for material removal rate based on the combination of electro discharge machine parameters and their levels is (i.e. pulse on time is 50µsecat level 3, voltage is 6V at level 2 and Current is 10A at level 3). and optimal solution obtained for surface roughness based on the combination of electro discharge machine parameters and their levels is (i.e. pulse on time is 40µsec at level 1, voltage is 7V at level 3 and Current is 8A at level 3).

2) ANOVA results indicate that contribution of Current on material removal rate is highest followed by pulse on time and voltage. Current is most dominant factor. This may be due to fact that Higher the Current, higher will be the energy applied and spark there by generating more amount of heat energy during this period.material removal rate is directly proportional to the amount of energy applied during pulse on time. Higher the value of pulse on time, higher will be the energy produced and this will lead to the generation of more heat energy.

3) Values of material removal rate and surface roughness obtained in confirmation experiment is least in all experiment conducted. Hence, good surface finish and maximum material removedwhile machining can be achieved using suggested level of parameters by Taguchi method.

4) Values of material removal rate surface roughness calculated using regression model correlates with experimental values with error less than 10%. Hence the model developed is valid and

experimental results of material removal rate and surface roughness with any combination of electro discharge machining parameters can be estimated within selected levels using the mode

IV. ACKNOWLEDGMENT

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