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Optimization of Wire Cut Electro Discharge Machining Process Parameters for HCHCr-D3 Steel by using Taguchi Technique

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Abstract: In this paper wire cut electro discharge process parameters are optimized by using Taguchi method. Process parameters considered for the study are pulse on time, pulse off time and current. High Carbon high Chromium (HCHCr-D3) steel is high tensile strength alloy which is mostly used in cold dies and tooling application that where high degree and dimensional accuracy is required. HCHCr-D3 alloy steel plate of rectangular shape has been used for machining operation. Performance of wire cut electro discharge machine (WEDM) with a molybdenum wire has been measured by material removal rate (MMR) and surface roughness (SR). In Taguchi method L9 orthogonal array has been selected. The analysis of variance (ANOVA) has been used to determine effect of each parameter on material removal rate (MRR) and surface roughness (SR).
Keywords: Taguchi Method, Signal to Noise Ratio, Optimization, Material Removal Rate, Surface Roughness.

I. INTRODUCTION

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 [1]. One such non-conventional process is wire cut electrical discharge machining (WEDM). Manufacturing process is modern manufacturing scenario. The WEDM utilizes the wire which acts as a tool upon passing current so as to erode the work material by the generation of sparks between the work and tool. The work piece and tool are partially or completely immersed in a dielectric fluid in order to remove the material by erosion and avoid over heating of the material. The gap between work piece and wire is usually ranges from 0.015-0.05 mm and is maintained constant by computer numerical control (CNC) system [2]. The process is mainly used in mould and dies making, aerospace and automotive industries [3]. Higher productivity with minimum cost is motive of almost all the industries. With increasing demand for quality product as well as for higher productivity, WEDM need to be performed more efficiently. Thus one of the most interesting and investigating areas is the modeling and optimization of process parameters to achieve a high quality product with the reduction of manufacturing cost [4].

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 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, Pulse off time 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

$$OA = Ln (Xm) \quad (1)$$

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 WEDM used in this study. All the experiments were conducted at Precise Metal Cut, Gala No. 1072, Mulay I square, K-232 MIDC Waluj, Aurangabad, M.S, India

Make and Model	ECO-32S
Work Table Size	500 x 850 mm
Working Table	320 x 400 mm
Max. Work piece Weight	400 kg
Machine Dimensions	1800x1300x1900
Machine Weight	2000 kg

Table 1 WEDM Machine Specification.

Figure.2.1 Setup Wire cut electro discharge Machine (WEDM)

C. Selection of Material

HCHCr-D3 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, Pulse off Time and Current of WEDM on material removal rate (MMR) and surface roughness (SR). Material HCHCr steel item code is D3.Chemical composition of HCHCr-D3 Steel is shown in Table 2

Composition	C	Si	Mn	Cr
Percentage	2-2.35 %	0.6%	0.6%	11-13.50%

Table 2 Chemical Composition of HCHCr-D3 Steel.

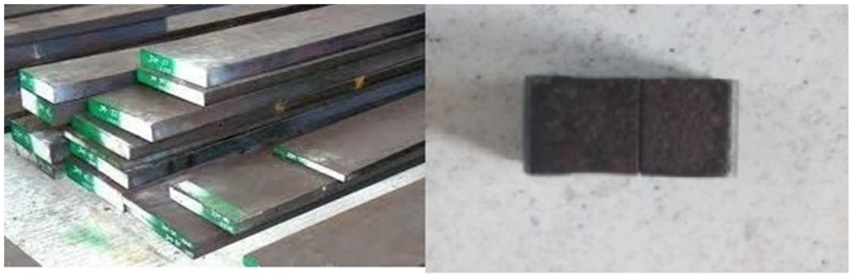

Figure 2.2 HCHCr-D3 Steel and a test specimen

D. OVAT for Pulse on Time

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

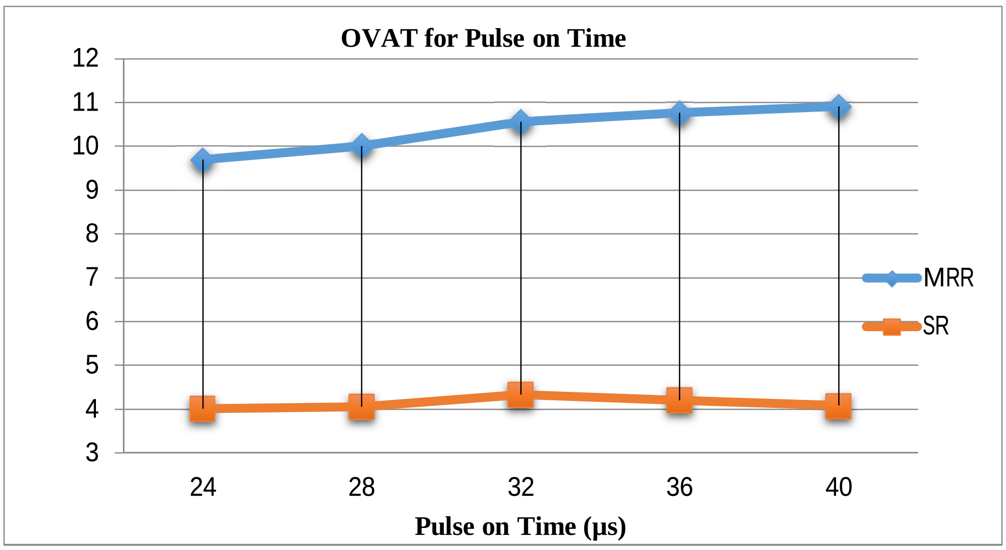

Figure 2.3 OVAT for Pulse on Time.

Pulse off time and current kept constant and pulse on time varied from 24 to 40 µsec. From the fig 2.3, it has been observed that as pulse on time increases from 24 to 40 µsec, the material removal rate and surface roughness increases drastically from 24 to 40 µse. also has been observed that, the rate of change of material removal rate and surface roughness is higher in the region of 28 to 36 µse hence this level of factor has been selected.

E. OVAT for Pulse off Time

Figure 2.4 shows variation in material removal rate and surface roughness with change in Pulse off time.

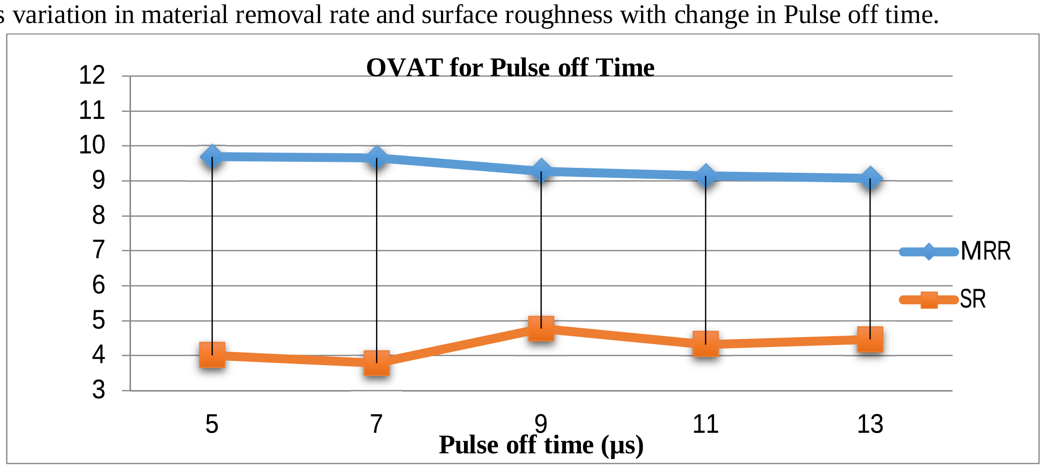

Figure 2.4 OVAT for Pulse off Time.

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It has been observed that, as Pulse off time increases, material removal rate and surface roughness decreases. The rate of change of material removal rate and surface roughness is higher in the region of 7 to 11 µsec hence this level of factor has been selected.

F. D. OVAT for Current

Figure 2.5 shows variation in material removal rate and surface roughness with change in current.

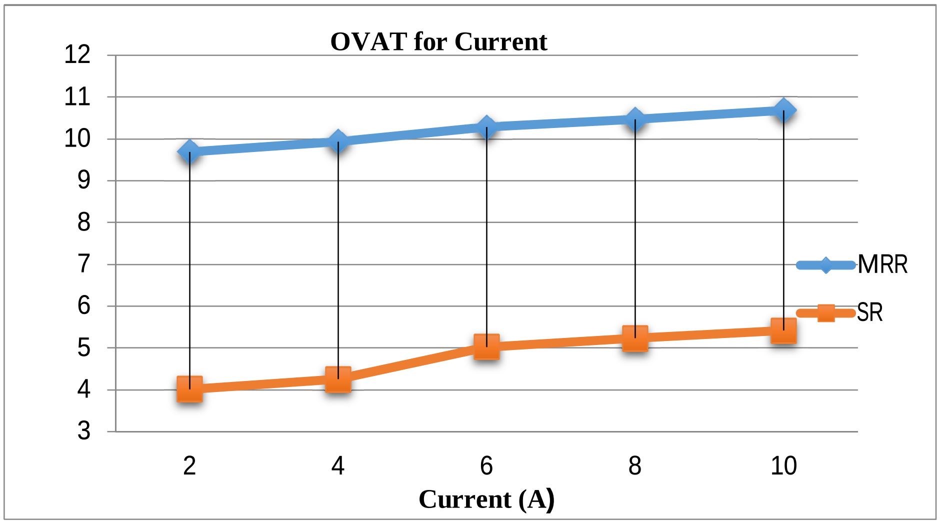

Figure 2.5 OVAT for Current.

It has been observed that, as Current are increases, material removal rate and surface roughness increases. The rate of change of material removal rate and surface roughness is higher in the region of Current is 2 to 6 A. hence this level of factor has been selected.

G. Levels of Input Parameters

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 first time. Table 3 shows three levels of input parameters selected for optimization study.

Sr. No	Level 1	Level 2	Level 3
Pulse on time (µs)	28	32	36
Pulse off time (µs)	7	9	11
Current (A)	2	4	6

Table 3 Levels of Input Parameters

III. RESULTS AND DISCUSSION

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

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.	Pulse on time (µs)	Pulse off time (µs)	Current (A)	Material Removal Rate (mm^3/min)	S/N Ratio
1	28	7	2	12.8290	22.1639
2	28	9	4	10.9704	20.8044
3	28	11	6	12.8759	22.1956
4	32	7	4	10.9051	20.7526
5	32	9	6	10.7347	20.6158
6	32	11	2	10.6567	20.5525
7	36	7	6	12.2769	21.7818
8	36	9	2	10.3215	20.2749
9	36	11	4	9.5767	19.6243

Table 4 L9 orthogonal array (OA) 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.

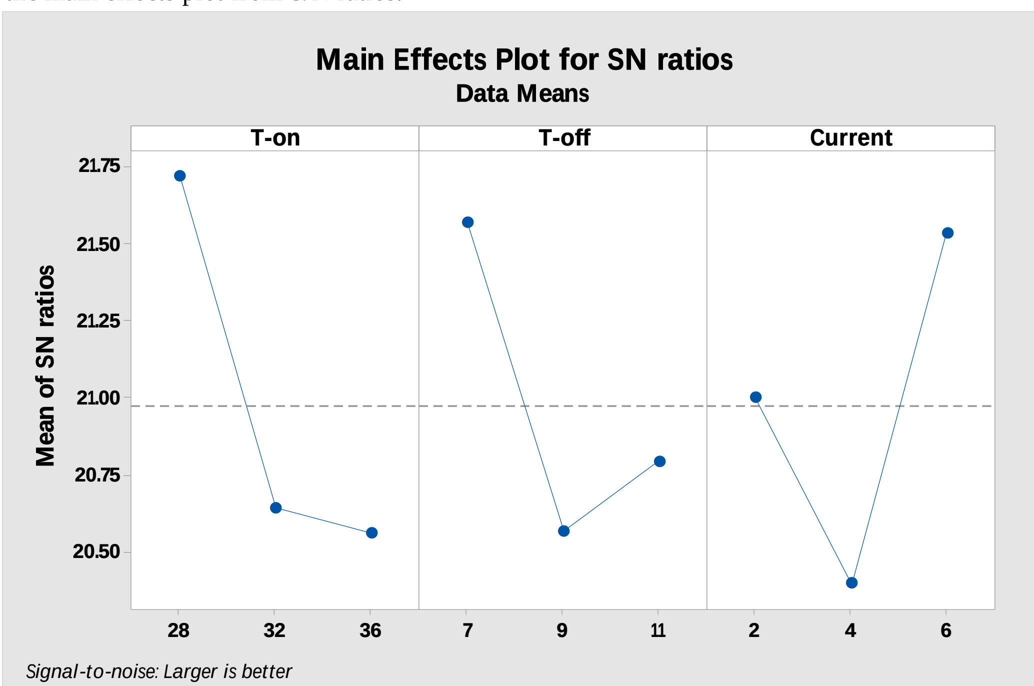

Figure.3.1 Main Effects Plot for S/N Ratio

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 S/N 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 process parameter is considered significant. [5] Relevance of the models is tested by 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-D3 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 5 shows results obtained from ANOVA.

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Pulse on Time	2	4.3823	2.19113	25.48	0.038	41.10
Pulse off Time	2	2.8297	1.41486	16.45	0.057	26.52
Current	2	3.2828	1.64142	19.08	0.050	30.77
Error	2	0.1720	0.08601			
Total	8	10.6669				

Table 5 ANOVA Result.

It shows that the pulse on time (41.10%), the pulse off time (26.52%) and the Current (30.77%) have major influence on the material removal rate. Contribution of Pulse on time (41.10%) 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 19 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 –

Material Removal Rate = 18.72 - 0.188 [Pulse on Time] - 0.242 [Pulse off time] + 0.173 [Current]

Table number 6 gives comparison between experimentally measured and predicted material removal rate by developed mathematical equation

Sr. No.	Experimental value	Predicted value	Error %
1	12.8290	12.108	5.95
2	10.9704	11.970	8.35
3	12.8759	11.832	9.62
4	10.9051	11.702	6.80
5	10.7347	11.564	7.17
6	10.6567	10.388	3.08
7	12.2769	11.296	8.68
8	10.3215	10.120	1.99
9	9.5767	9.982	4.06

Table 6 Experimental and Predicted Values of Material Removal Rate

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Difference between material removal rate 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 predicted values calculated using regression equation.

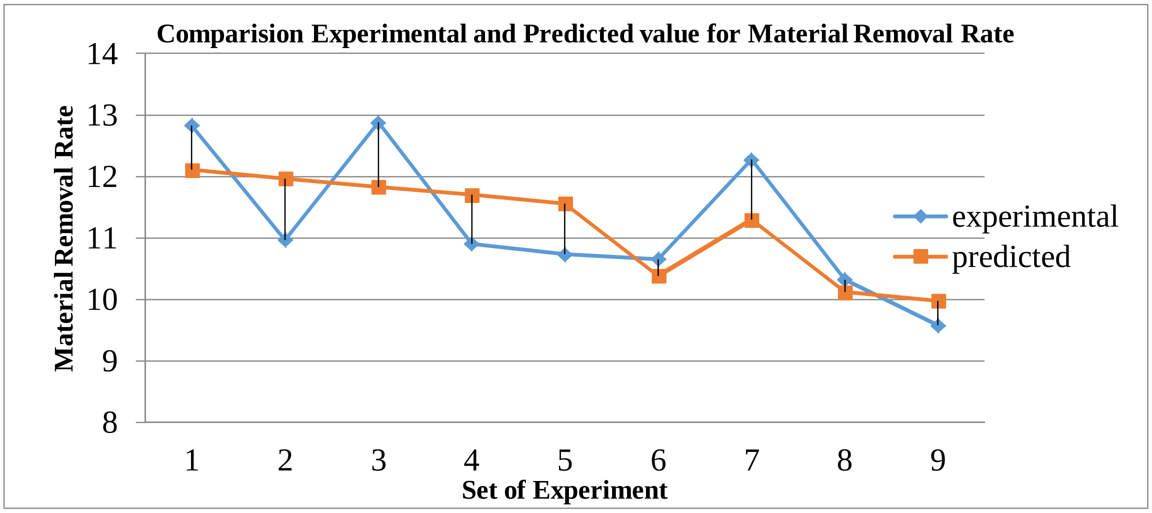

Figure 3.2 Comparison between Experimental and Predicted value of Material removal rate.

E. Confirmation Experiment Result

Table 7 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	12.60	13.19	3.04

Table 7 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the material removal rate 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 8 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)	Pulse off time (μs)	Current (A)	Surface Roughness (μm)	S/N Ratio
1	28	7	2	7.428	-17.4174
2	28	9	4	4.580	-13.2173
3	28	11	6	6.934	-16.8197
4	32	7	4	5.511	-14.8246
5	32	9	6	6.040	-15.6207
6	32	11	2	4.565	-13.1888
7	36	7	6	8.637	-18.7273
8	36	9	2	6.039	-15.6193
9	36	11	4	4.918	-13.8358

Table 8 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.

G. Main Effects of Surface Roughness

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. surface roughness (SR) can be understood. Pulse on time 32µsec at level 2, Pulse off time 11µsec at level 3, Current 4 A at level 2 gives the highest signal to noise (S/N) ratio values. The levels at which highest S/N ratio obtained from S/N ratio plot taken as optimum levels setting for machine parameters.

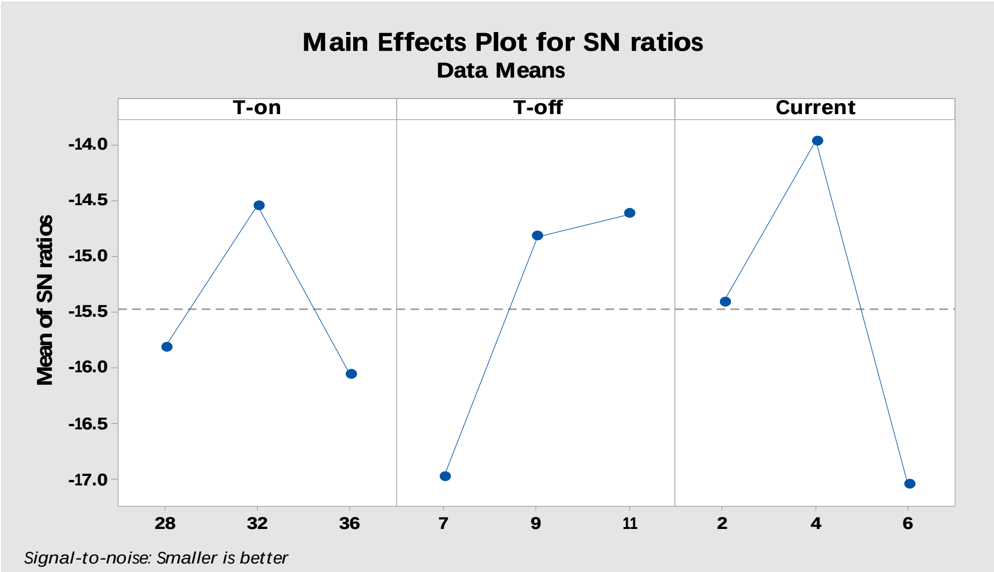

Figure.3.3 Main Effects Plot for S/N Ratio

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. [5] Relevance of the models is tested by 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 surface roughness (SR) have an influence on the HCHCr-D3 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 9 shows results obtained from ANOVA

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Pulse on Time	2	2.2787	1.13933	23.65	0.041	14.88
Pulse off Time	2	5.6501	2.82504	58.64	0.017	36.91
Current	2	7.2816	3.64079	75.57	0.013	47.57
Error	2	0.0964	0.04818			
Total	8	15.3067				

Table 9 ANOVA Result.

It shows that the pulse on time (14.88%), the pulse off time (36.91%) and the Current (47.57%) have major influence on the Surface roughness. Contribution of current (47.57%) 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 19 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 –

Surface Roughness = 6.88 + 0.027[Pulse on Time] - 0.430 [Pulse off Time] + 0.298 [Current]

Table number 10 gives comparison between experimentally measured and predicted surface roughness by developed mathematical equation.

Sr. No.	Experimental value	Predicted value	Error %
1	7.428	7.220	2.86
2	4.580	4.958	7.62
3	6.934	6.694	6.58
4	5.511	5.926	7.01
5	6.040	6.662	9.33
6	4.565	4.610	3.97
7	8.637	7.360	3.31
8	6.039	7.298	4.11
9	4.918	5.314	7.45

Table 10 Experimental and Predicted Values of Surface Roughness

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 predicted values calculated using regression equation.

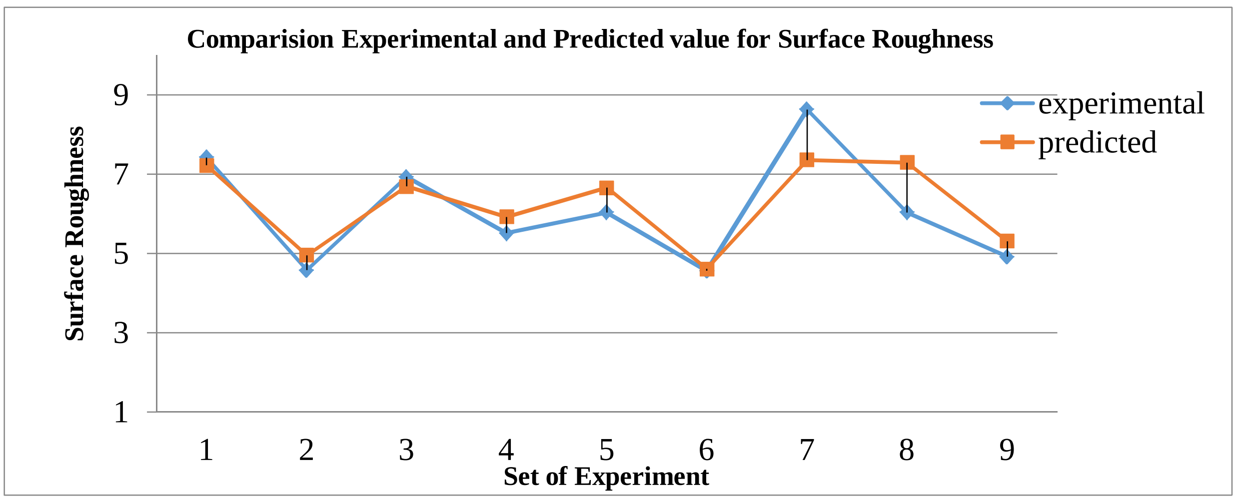

Figure 3.4 Comparison between Experimental and Predicted value of Surface Roughness.

J. *Confirmation Experiment Result*

Table 11 shows the difference between value of surface roughness of confirmation experiment and value predicted from regression model developed.

Parameter	Model value	Experimental value	Error %
Surface Roughness	4.206	3.958	5.89

Table 11 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 5.89%. This indicates that the experimental value correlates to the estimated value.

IV. CONCLUSIONS

In this study the influence of process parameters such as pulse on time, pulse off time and current and their optimization for HCHCr D-3 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 28µsec at level 1, pulse off time is 7µsec at level 1 and Current is 6A 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 32µsec at level 2, pulse off time is 11µsec at level 3 and Current is 4A at level 2).
2) ANOVA results indicate that contribution of pulse on time on material removal rate is highest followed by pulse off time and current. Pulse on time is most dominant factor. This may be due to fact that Higher the pulse on time, 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 removed while machining can be achieved using suggested level of parameters by Taguchi method.
4) Values of material removal rate and 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 WEDM parameters can be estimated within selected levels using the mode

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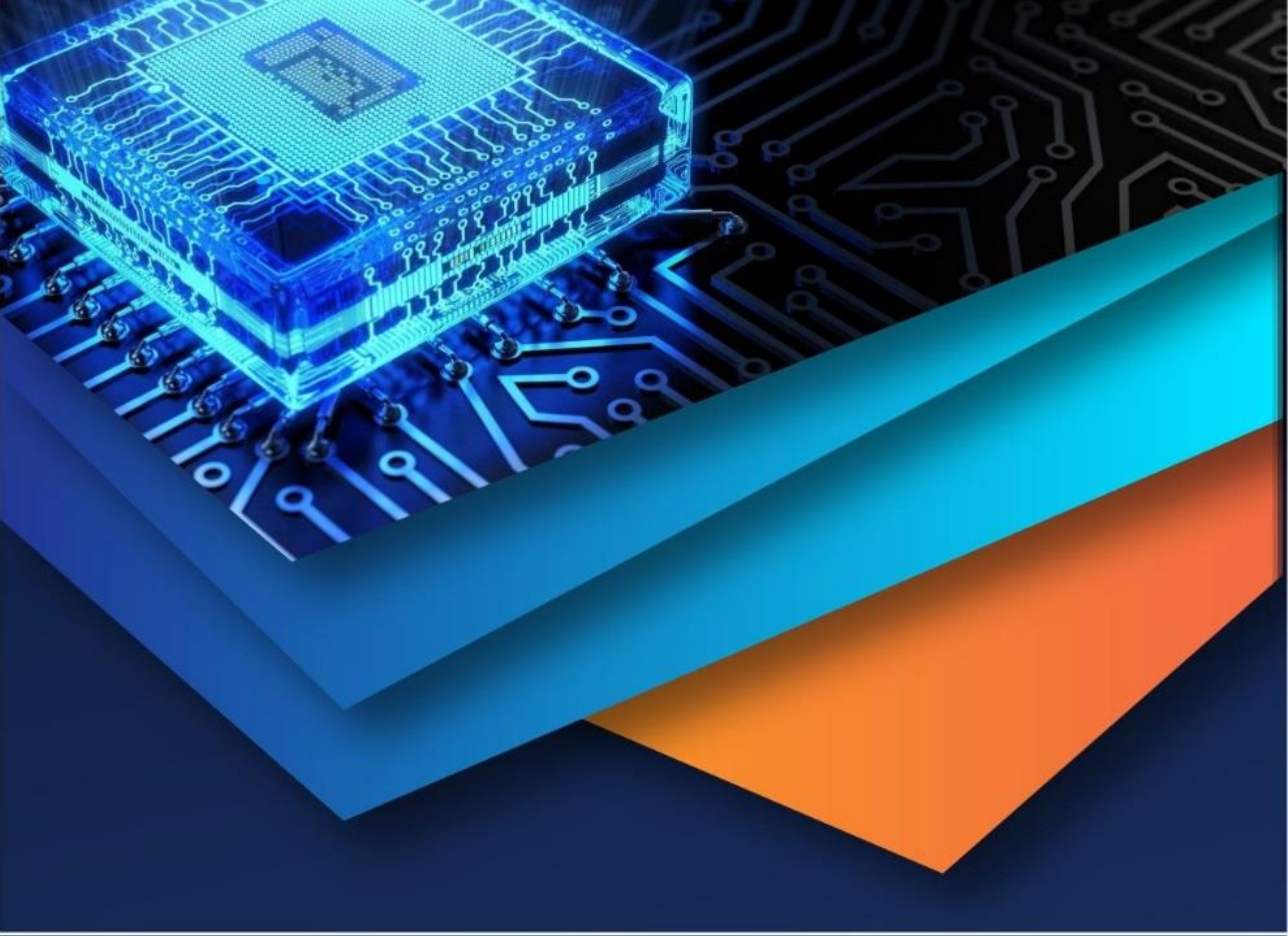
REFERENCES

[1] Senkathir.S, Aravind.R, Manoj Samson.R and.Arun Raj.A.C. Optimization of machining parameters of Inconel 718 by WEDM using Response surface methodology. Springer nature Singapore pvt Ltd, Advances in Manufacturing Processes, India, 2019, 978-981.
[2] Suthan S, Muralidharan K. Experimental analysis optimization of process parameters of wire edm on stainless steel316, International Research Journal of Engineering and Technology. 2018. Vol: 05 Issue: 06 | June-2018, p-ISSN: 2395-0072.
[3] MalakSoni, Ronak J Rana, and Prof. Alok B Choudhary. Comparative Study of Electro – Discharge Machining with the use of Additional Rotary Tool EDM Performance during Machining of EN-8 Material, International Journal of Scientific Research in Science and Tchnology.2018 Volume 4, Issue 8
[4] Suryawanshi.M.V. and N.K.Kamble.N.K. Analysis of Effect of Cutting Parameter of Wire Electric DischargeMachining on Material Removal Rate and Surface Roughness: A Review, International Research Journal of Engineering and Technology.2018 e-ISSN: 2395-0056, Volume: 05 Issue: 06 | p-ISSN: 2395-0072.
[5] Pradeep Singh, Arun Kumar Chaudhary, Tirat Singh and Amit Kumar Rana. "Experimental investigation of wire EDM to optimize dimensional deviation of EN8 Steel through Taguchi's technique. International Research Journal of Engineering and Technology. 2018.Volume: 02 Issue: 03e-ISSN: 2395-0056, | p-ISSN: 2395-0072
[6] Kishan.B, SudeerPrem Kumar, Gajanana.S, Buchaiah, Gaffar.M. "Development of Mathematical Model for Metal Removal Rate on EDM using Copper and Brass Electrodes" Proceedings of 7thInernational Conference on Material Processing and Characterization, Elsevier Ltd.2018.
[7] Anjaneya Acharya, GirijaNandanArka, RashmiRanjan Panda. Experimental Investigation of EDM Machining Parameters to Machine EN8 Material by using Heat Treated Tool, International Journal of Engineering and Management Research. 2017.Volume-7, Issue-2, March-April 2017ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962.Pg No:321-327



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