Optimization of Process Parameters Wire Cut Electro Discharge Machining (WEDM) on HCHCr-D2 Steel Material

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***Abstract**:* With the increasing demands of high surface finish and machining of complex shape geometries, conventional machining process are now being replaced by non-traditional machining processes. Wire EDM is one of the non-traditional machining processes which is basedon Electrical Discharge Machining Process, which is also called electro-erosion machining process In the present research parametric analysis of wire EDM parameter is performed by Taguchi method on surface roughness (SR) and material removal rate (MRR). The Design of experiments is carried out considering Taguchi technique with four input parameters, namely, pulse-on, pulse off, and voltage. L9 orthogonal array is used to conduct experiments. ANOVA is used to find out the most significant parameter that affects the surface roughness. Optimizations of parameters are done by finding out the S/N ratios of each experiment runs. Regression Analysis is carried out togenerate a mathematical model of surface roughness, material removal rate and to predict the value obtained from the optimal parameter settings.

Keywords: WEDM, Taguchi method, Annova, SR, MRR

I. INTRODUCTION

Wire EDM removes material; but wire EDM removes material with electricity by means of spark erosion. Therefore, material must be electrically conductive. Rapid DC electrical pulses are generated between the wire electrode and the work piece. Between the wire and the work piece is a shield of deionized water, called the dielectric. Pure water is an insulator, but tap water usually contains minerals that cause the water to be too conductive for wire EDM. To control the water conductivity, the water goesthrough a resin tank to remove much of its conductive elements—this is called deionized water. As the machine cuts, the conductivity of the water tends to rise, and a pu automatically forces the water througha resin tank when the conductivity of the water is too high. When sufficient voltage is applied, the fluid ionizes. Then a controlled spark precisely erodes a small section of the workpiece, causing it to melt and vaporize. These electrical pulses are repeated thousands of times per second. The pressurized cooling fluid, the dielectric, cools the vaporized metal and forces the resolidified eroded particles from the gap. The dielectric fluid goes through a filter which removes the suspended solids. Resin removes dissolved particles; filters remove suspended particles. To maintain machine and part accuracy, the dielectric fluid flows through a chiller to keep the liquid at a constant temperature.

The servo mechanism prevents the wire electrode from shorting out against the workpiece and advances the machine as it cuts the desired shape. Because the wire never touches the workpiece, wire EDM is a stress-free cutting operation. The wire electrode is usually a spool of brass, or brass and zinc wire.

II. MATERIALS AND METHODOLOGY

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.. 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 voltage were identified as most predominant parameters affecting the WEDM.Based on the observation, Taguchi method has been used to optimize the process parameters.. 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

Figure.1 Setup Wire cut electro discharge Machine

Make and Model	Electara-Electronica
Work Table Size	635 x 475 mm
Max. Work piece Weight	300 kg
Machine Dimensions	1800x1300x1900
Machine Weight	2000 kg
Wire Diameter	0.15-0.30

Table 3.3 WEDM Machine Specification.

C. Selection of material

HCHCr-D2 Steel

- Superior Strength & Toughness
- Corrosion Resistant
- Can withstand Extreme Temperature
- Capable of being fabricated into a variety of parts

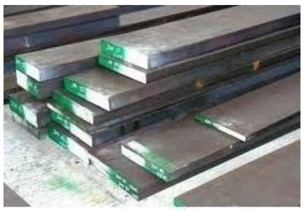


Fig 2. HCHCr-D2 Steel

Brass Electrode (Wire)

- Excellent heat conducting
- Excellent electrical conductivity
- Good corrosion resistance
- ood machinabilty
- No magnetic
- It should have High Melting Point

Fig 3 Electrode (wire)

III. RESULTS AND DISCUSSION

A. Experimental Result

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

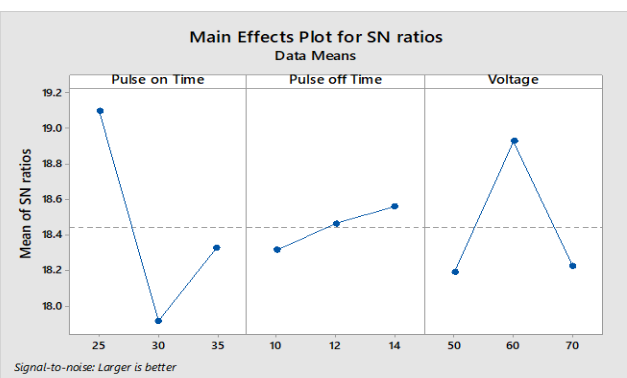
Experiments	Inputs Factors			Output Responses			
Trial No.	**Pulse on time ((µs)**	**Pulse offtime (µs)**	**Voltage(V)**	**MRR**	**S/N Ratio**	**SR**	**S/N Ratio**
1	25	10	50	9.278	19.3491	3.874	-11.7632
2	25	12	60	9.014	19.0984	4.019	-12.0824
3	25	14	70	8.293	18.3742	3.099	-9.8244
4	30	10	60	7.798	17.8397	4.005	-12.0521
5	30	12	70	7.521	17.5255	3.479	-10.8291
6	30	14	50	7.697	17.7264	3.569	-11.0509
7	35	10	70	8.126	18.1975	3.178	-10.0431
8	35	12	50	8.964	19.0500	2.985	-9.4989
9	35	14	60	9.267	19.3388	3.429	-10.7033

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/Nratio is minimum for all experiment.

B. Main Effects of MRR and SR

Figure 4 shows the main effects plot from S/N ratios .



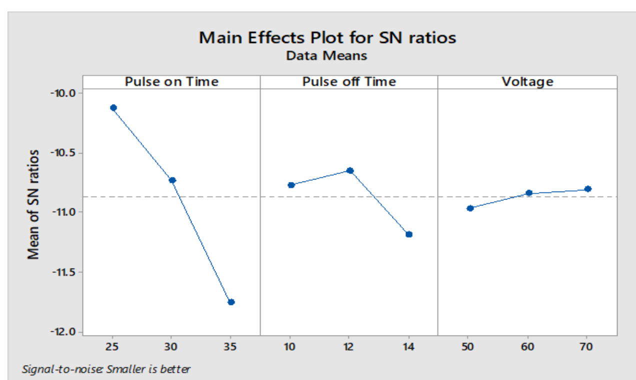


Figure.4 Main Effects Plot for S/N Ratio

From main effects plot for S/N ratio, parametric effect on response characteristic i.e. material removal rate and surface roughness can be understood. The optimal input parameters were pulse on time 25µs (level 1), 7 µs pulse off time 14 µs (level 3) and voltage 60V (level 2) and The optimal input parameters were pulse on time 25µs (level 1), 11 µs pulse off time 12 µs (level 2) and 70v voltage (level 3). gives the highest signal to noise ratio values. The levels at which highest S/N ratio obtained from S/N ratio plottaken 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 voltage of the material have an influence on the Ti alloy. The last column ofcumulative 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 analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
T-on	2	1.10975	0.5548	5.21	0.030	33.62
T-off	2	0.96586	0.4829	4.54	0.036	29.26
Voltage	2	1.01217	0.5060	4.75	0.031	30.66
Error	2	0.21270				
Total	8	3.30071				

Table 5 ANOVA Resul for MRR

It shows that the that the pulse on time (33.62%), the pulse off time (29.26%) and the voltage (29.26%) havemajor influence on the material removal rate. Contribution of pulse on time (30.26%) is highest among all three parameters hence it is most dominating parameter while pulse off time is least affectingparameter.

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
T-on	2	1.10975	0.5548	5.21	0.685	33.62
T-off	2	0.96586	0.4829	4.54	0.180	29.26
Voltage	2	1.01217	0.5060	4.75	0.095	30.66
Error	2	0.21270				
Total	8	3.30071				

Table 6 ANOVA Result for SR

the pulse on time (45.81%) %), the pulse off time (31.85%) and the voltage (18.85%) have major influence on the material removal rate. Contribution of pulse on time (45.81%) is highest among all threeparameters hence it is most dominating parameter while voltage is least affecting parameter.

D. Confirmation Experiment Result

Table 7 shows the difference between value of material removal rate of confirmation experiment andvalue predicted from regression model developed.

Parameter	Model value	Experimental value	Error %
Material Removal Rate	8.878	9.393	5.80

Table 7 Confirmation Experiment Result

Parameter	Model value	Experimental value	Error %
SR	3.142	2.971	5.44

Table 7 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the MRR and SR 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 5.80 and 5.44%. 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 voltage and their optimization for HCHCr-D2 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 25µs (level 1), 7 µs pulse off time 14 µs (level 3) and voltage 60V (level 2).) 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 25µs (level 1),11 µs pulse off time 12 µs (level 2) and 70v voltage (level 3).).

2) ANOVA results indicate that contribution of pulse on time on material removal rate is highestfollowed by pulse off time and voltage. 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 andsurface 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 canbe estimated within selected levels using the mode

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