Optimization of Process Parameters in WEDM by using Taguchi Method

Suresh Kumar[1], Sumit Jain[2], Amit Ahlawat[3], Preety Rani[4]

[1]M.tech Student, Department of Mechanical Engineering, CBS Group of Institutions, Jhajjar, Haryana, India
[2,4]Assistant professor, Department of Mechanical and Automation Engineering, HMR Institute of Technology and Management, Delhi, India
[3]Assistant professor, Department of mechanical engineering, CBS Group of Institutions, Jhajjar, Haryana, India

Abstract— *This research represents the parametric optimization of Wire EDM on machining die steel DC53. The objective of the present work was to investigate the effects of the various Wire EDM process parameters using Taguchi on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized. The machining parameters selected for present research were Pulse on time, pulse off time and wire feed. A series of nine experiments were conducted using Wire EDM. The ANOVA was employed to analyze the influence of these parameters on Material removal rate during machining process. The results showed that the input parameters setting of pulse on time at 120µs, pulse off time at 60µs and wire feed at 6mm/min have given the best results for optimization of Material removal rate.*

Keywords— Wire electric discharge machining (WEDM), material removal rate.

I. INTRODUCTION

Wire Electric Discharge Machining (WEDM) is a non-traditional process of material removal from electrically conductive materials to produce parts with intricate shapes and profiles. This process is done by using a series of spark erosion. These sparks are produced between the work piece and a wire electrode (usually less than 0.30 mm diameter) separated by a dielectric fluid and erodes the work piece to produce complex two and three dimensional shapes according to a numerically controlled pre-programmed path. The sparks produce heating and melt work piece surface to form debris which is then flushed away by dielectric pressure. During the cutting process there is no direct contact between the work piece and the wire electrode. Wire Electrical Discharge Machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes.

II. REVIEW

The literature on machining by using WEDM is given as: Lung et al. [2004] adopted an experimental investigation of ultra thin wires as electrode. Until now only a few scientific works have been dealing with cutting by WEDM using wires with a diameter below 50 µm. Typical ultra thin wire diameters are 20, 25, 30 and 50 µm. A special set-up to use 20 and 25 µm wires with an existing machine which can run wires up to 30 µm was designed and constructed. Kanlayasiri and Boonmung [2007] carried out the of the effects of machining variables(peak current, pulse-on time, pulse-off time, and wire tension) on the surface roughness of WEDMed DC53 die steel using Analysis of variance (ANOVA) technique . Results from the analysis show that pulse-on time and pulse-peak current are significant variables to the surface roughness of WEDMed DC53 die steel. Singh and Garg [2009] investigated the effects of various process parameters of WEDM like pulse on time (TON), pulse off time (TOFF), gap voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT) to reveal their impact on material removal rate of hot die steel (H-11) using one variable at a time approach. Kapoor et al. [2010] Studied the effect of different Wire electrodes (copper, brass and coated wire electrodes) on cutting speed and dimensional 22 accuracy. It concluded that for different materials different metal wire electrodes are preferred as they offer better response parameters such as better surface roughness, higher MRR etc. Kapoor et al. [2011] discussed the results of the effect of Cryogenic treated brass wire electrode on the surface of an EN-31 steel machined by WEDM using Full factorial experimental design strategy with the selection of process parameters namely type of wire electrode (untreated and cryogenic treated brass wire electrodes), Pulse width, and wire tension. The process performance is measured in terms of surface roughness (SR). Sharma and Khanna [2012] Determined the effect of parameters of WEDM such as pulse width, time between two pulses, maximum feed rate, servo reference mean voltage, short pulse time and wire mechanical tension. The result of this experiment is that pulse width and time between two pulses were significant variables to the surface roughness of wire-EDMed cryogenic treated D-3. Rao et al. [2013] carried out the influence of process parameter like discharge current, job thickness, on the machining criteria such as cutting speed, spark gap, material removal rate on HC-HCr die steel are determined.

III. EXPERIMENTAL SET UP AND PROCESS PARAMETER

Taguchi experimental design (single response optimization)

Taguchi method was developed by Dr. Genichi Taguchi of Japan. The Taguchi method involves reducing the variations in a process by using robust design of experiments. The main objective of Taguchi method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The Taguchi experimental design involves orthogonal array to arrange the parameters affecting the process and the levels at which they should be varies. Instead to test all possible combinations as by the factorial design, the Taguchi method tests pairs of combinations. This also provides data to determine which factors most affect product quality with a minimum number of experimentation, thus saving time as well as resources. The Taguchi method is best used under the variable of factors between 3 to 50, few interactions between variables, and when only a few variables contribute significantly.

Machine Tool

The experiments are carried out on a wire-cut EDM machine (Model DK77) of Zhongyuan Machine Tools Ltd. The WEDM machine tool has the following specifications given in Table 1.

Table.1: Specification of WEDM Machine

1	Table size	440 x 650 mm
2	Design	Fixed Column, Moving Table
3	Max. work piece height	200
4	Max. work piece weight	500
5	Main table traverse (X, Y)	300, 400 mm
6	Auxiliary table traverse	80, 80 mm
7	Max. taper cutting angle	±20°/50 mm
8	Max. wire spool capacity	6 Kg
9	Wire electrode diameter	0.15, 0.20,0.25 mm
10	Interpolation	Linear & Circular
11	Input Power supply	3 phase, AC 380 V, 50 Hz
12	Average power consumption	6 to 7 KVA
13	Dielectric	Deionised water

Work Piece Material

The work material selected for the study was Die steel DC53 with high tensile strength, shock resistance, good ductility and resistance to wear. DC53 is a new general-purpose cold work die and mold steel whose strength and toughness approach those of high-speed steels. Chemical composition of the die steel DC53 is given in following Table-2.

Selection of parameters

The experiments were performed on wire-cut EDM machine Various input parameters varied during the experimentation are pulse on time (T_{on}), pulse off time (T_{off}) and wire feed (WF). The effects of these input parameters are studied on MRR. The selection of parameters along with their range is shown in table 3.

Table.2: Chemical Composition of Die Steel DC53

Constituent	C	Si	Mn	Cr
Percentage Composition	0.90-1.10	0.80-1.20	≤0.40	7.50-8.50
Constituent	P	S	Mo	V
Percentage Composition	≤0.03	≤0.03	1.80-2.20	0.20-0.50

Table.3: Selection and range of parameters

Sr. No.	Process Parameters	Symbols Used	Units	Range Used
1.	Pulse On Time	T_{on}	µs	100-120
2.	Pulse Off Time	T_{off}	µs	40-60
4.	Wire Feed Rate	WF	m/min	4-8

IV. EXPERIMENTAL DATA

The experimental work is carried out using Taguchi methodology. The design is prepared with the help of Taguchi design of experimentation by using 'Minitab-16' which is used to create experimental designs.

Based on the experimental design, the specimens were prepared and the values of selected machining characteristics i.e. MRR is reported in Table 4. And the value of MRR for each of nine experiments performed on WEDM is also shown in table 4.

Table.4: Experimental Design according to Taguchi

	Factor 1	Factor 2	Factor 3		
Run	**A (T_{on})**	**B (T_{off})**	**C (WF)**	**MRR**	**MRR (S/N Ratio)**
	μs	**μs**	**mm/min**	**mm^3/min**	
1	100	4	4	3.869	11.7520
2	100	50	6	4.760	13.5521
3	100	60	8	5.671	15.0732
4	110	40	6	6.199	15.8464
5	110	50	8	2.675	8.5465
6	110	60	4	8.564	18.6535
7	120	40	8	3.468	10.8016
8	120	50	4	4.986	13.9550
9	120	60	6	9.243	19.3163

ANALYSIS OF RESULT FOR SINGLE RESPONSE OPTIMIZATION

The parameters design strategy consist of selection of optimum parameter then the mean of the response (μ) at the optimum condition is predicted and at last confirmation experiment is a final step in verifying the conclusions. The ANOVA identifies the significant parameters. The estimate of the mean (μ) is only a point estimate based on the average of results obtained from the experiment. Statistically this provides a 50% chance of the true average being greater than μ. The values of MRR along with S/N ratio for various experiments in shown in table

The confirmation experiment is a final step in verifying the conclusions from the previous round of experimentation. The optimum conditions are set for the significant parameters (the insignificant parameters are set at economic levels) and a selected number of tests are run under specified conditions. The average of the confirmation experiment results is compared with the anticipated average based on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended to verify the experimental conclusion.

Table.5:Response Table for Material Removal Rate (Means)

Level	**A**	**B**	**C**
1	4.767	4.512	5.806
2	5.813	4.140	6.734
3	5.899	7.826	3.938
Delta	1.132	3.686	2.796
Rank	3	1	2

Analysis of Variance (ANOVA)

The ANOVA (general linear model) for raw data has been performed to identify the significant parameters and to quantify their effect on the performance characteristic. The ANOVA for Means is given in Tables 6. The most favorable conditions or optimal levels of process parameters have been established by analyzing response curves of raw data.

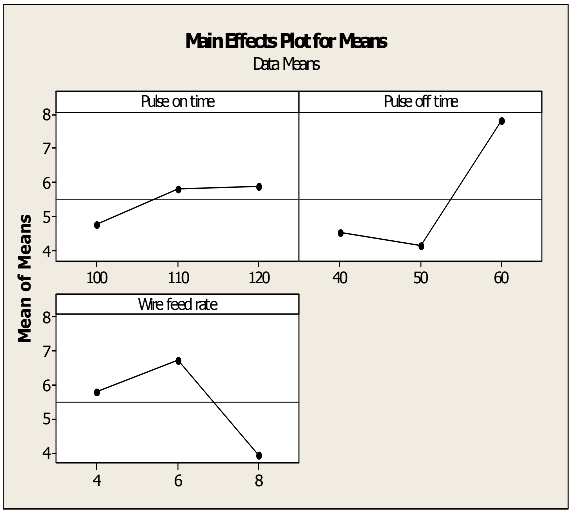

Fig.1: Effects of Process Parameters on MRR

Effect on Material Removal Rate

It can be observed from Fig. 1 that the pulse off time affects the metal removal rate very significantly. Moreover, the different input parameters used in the experimentation can be ranked in the order of increasing material removal rate as tool pulse off time, wire feed and pulse on time. From the Table 5, the highest metal removal rate has been recorded with pulse on time (at level 3), pulse off time (at level 3) and wire feed (at level 2). In WEDM, the pulse off time is most significant factor for increasing the material removal rate, wire feed is the second significant factor and pulse on time is the third significant factor. In order to estimate the contribution of each factor towards the variation of machining performance in terms of material removal rate for WEDM on Die steel DC53. Analysis of Variance test is conducted on the results obtained from the experimentation. The ANOVA test summary for material removal rate has been recorded for both the average response (Table 6). The analysis of results showed that "$A_3B_3C_2$" is the optimal parameter setting for the Maximization of MATERIAL REMOVAL RATE. Hence, it can be concluded that "input parameters settings of pulse on time at 120µs, pulse off time at 60µs and wie feed at 6mm/min have given the optimum results for MRR, in WEDM of Die steel DC53.

Table.6:Analysis of Variance for Material Removal Rate (Means)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contri-bution
T_{on}	2	2.3837	2.3837	1.1919	9.95	0.091	6.07%
T_{off}	2	24.7049	24.7049	12.3524	103.09	0.010	62.92%
WF	2	12.1689	12.1689	6.0844	50.78	0.019	30.99%
Residual Error	2	0.2397	0.2397	0.1198			
otal	8	39.497					

CONFIRMATION EXPERIMENT

In order to validate the results obtained, three confirmation experiments were conducted for each of the response characteristics (MRR) at optimal levels of the process variables. The average values of the characteristics were obtained and compared with the predicted values. The results are given in Table 7.

Table.7: Predicted Optimal Values, Confidence Intervals and Results of Confirmation Experiments

Performance Measure / Response	Optimal Set of Parameters	Predicted Optimal Value	Predicted Confidence Intervals	Experimental Value
MRR	$A_3B_3C_2$	9.473 mm^3/min	CI_{CE} : 8.04 < μ_{MRR} < 11.43	9.243 mm^3/min

V. CONCLUSIONS

Basically, this study evaluates the machining performance of WEDM on Die-steel DC-53. All the experiments trials, planning and analysis were executed using Taguchi design of experiment and the total number of experimentation by Taguchi DOE were nine by using L_9 array. The analysis is done by ANOVA method applied in this study were to determine the optimum condition of machining parameters and the significance of each parameter to the performance of machining characteristics.

The following conclusions are drawn based on the performance of machining characteristics studied in this research work namely, Material removal rate (MMR):

1. All the selected parameters i.e. Pulse on time, pulse off time and wire feed significantly affect the material removal rate in WEDM on Die steel DC-53.
2. In WEDM, the pulse off time is most significant factor for increasing the material removal rate, wire feed is the second significant factor and pulse on time is the third significant factor
3. It can be concluded that "input parameters settings of pulse on time at 120µs, pulse off time at 60µs and wire feed at 6mm/min have given the optimum results for MRR, in WEDM of Die steel DC53.

REFERENCE

[1] Kanlayasiri, K., Boonmung, S. (2007), "An investigation on effects of wire-EDM machining parameters on surface roughness of newly developed DC53 die steel", Journal of Materials Processing Technology, 187–188, pg.26–29

[2] Kapoor, J., Singh, S. and Khamba, J.S. (2010), "Recent Developments in Wire Electrodes for High Performance WEDM", Proceedings of the World Congress on Engineering, 2

[3] Kapoor, J., Singh, K.J., Singh, S. (2011),"Effects of cryogenic treated wire electrode on the surface of an EN-31 steel machined by WEDM", National Conference on Advancements and Futuristic Trends in Mechanical and Materials, Vol.1 No.1 July-Dec.2011

[4] Sharma, N. and khana, R. (2012), "Optimization of process parameters of cryogenic treated D-3 in WEDM by Taguchi Approach", International Journal of Engineering Research and Applications, Vol. 1, Issue 3, pg.546-553.

[5] Rao, S., Sivanaga, M. and Parameswara, V.S. (2013)" Parametric Evaluation for Machining Die-Steel with WEDM", International Journal of Scientific and Research Publications, Volume 3, Issue 4, April 2013, pg. 2250-3153.

[6] Lung, D. Thomaidis, D., Antonoglou, G., Klocke, F. (2004) " Using ultra thin electrodes to produce micro-parts with wire-EDM", Journal of Materials Processing Technology, 149, (2004), 579–584.
[7] N Sharma, R Khanna and RD Gupta, Multi Response Optimization of WEDM Process Parameters with RSM, Procedia Engineering, 64, 2013, 710-719.
[8] N Sharma, A Singh, R Sharma, and Deepak, Modelling the WEDM Process Parameters for Cryogenic Treated D-2 Tool Steel by integrated RSM and GA. Procedia Engineering, 97, 2014, 1609-1617.