ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

Optimisation and Influence of Process Parameters for Machining with Wire Cut EDM Using Taguchi's Technique

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ABSTRACT :- In the field of manufacturing we needs the process in with our requirements for product will fulfil like production rate, quality, performance of machine, production time, accuracy, precision work etc. To achieve that we moved from conventional machining to non-conventional machines, which provide better manufacturing products. Also the optimisation of processes is necessary to determine the optimal or efficient process parameters of machine for particular product and its material. In this paper Wire cut Electric discharge machine is selected and optimisation of it parameters are carried out for M-35 HSS with 5% Cobalt material as work material. Material removal rate (MRR) is taken as the response parameter. For getting optimal vales of process parameters for higher value of MRR a statistical Taguchi's method is used. A design of experiment is created for process parameters like pulse on time (T_{on}), pulse off time (T_{off}), peak current (I_p), spark voltage (S_v) and orthogonal array of L9 is formed. With the use of MINITAB 18 statistical software analysis software is used.

KEYWORDS :- M-35 HSS with 5% Cobalt material, material removal rate (MRR), Taguchi's design of experiment, orthogonal array, MINITAB 18.

I. INTRODUCTION

Wire EDM machining (Electrical Discharge Machining) is an electro thermal production process in which a thin single strand metal wire in conjunction with de-ionized water (used to conduct electricity) allows the wire to cut through metal by the use of heat from electrical sparks. Due to the inherent properties of the process, wire EDM can easily machine complex parts and precision components out of hard conductive materials. Wire EDM machining works by creating an electrical discharge between the wire or electrode and the work piece. As the spark jumps across the gap, material is removed from both the work piece and the electrode. To stop the sparking process from shorting out, a nonconductive fluid or dielectric is also applied. The waste material is removed by the dielectric, and the process continues. In wire EDM machining, a thin single-strand metal wire, usually brass, is fed through the work piece. The wire, which is constantly fed from a spool, is held between upper and lower guides. The guides move in the X-Y plane, and sometimes the upper guide can also move independently giving rise to transitioning shapes (circle on the bottom square at the top). This gives the Wire EDM the ability to be programmed to cut very intricate and delicate shapes. The wire-cut uses water as its dielectric with the water's resistivity and other electrical properties carefully controlled by filters and de-ionizer units. Pure water is an insulator, but tap water usually contains minerals that cause the water to be too conductive for WEDM, The deionised water cools and flushes away the small particles from the gap.[1]

In this research paper optimisation of Wire cut EDM machine process parameter is carried out using Taguchi's design of experiment and its analysis. Material removal rate is taken as response parameter to aim high production rate. Water is taken as the dielectric fluid and coated wire as electrode. Optimal parameters are find for the M-35 HSS with 5% Cobalt material.

II. BASIC PRINCIPLE OF WIRE CUT EDM

Wire cut EDM process is non-conventional machining process in with the machining is carried out by thermo-electric spark erosion process. In this process conductive material can be machining irrespective of it hardness. Electric spark is generated between wire and workpiece, both are having gap between them called spark gap which allows spark to

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International Journal of AdvancedResearch in Science, Engineering and Technology
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occur, waste material is eroded and removed by dielectric fluid which continuously flowing through the gap. Filtration mechanism is used to make dielectric fluid reusable. The wire is also continuously flowing at fixed rate through the work. Using this machine we can form complex shapes without bothering of its hardness, toughness. The sketch diagram of mechanism of wire cut EDM is shown in figure 1.

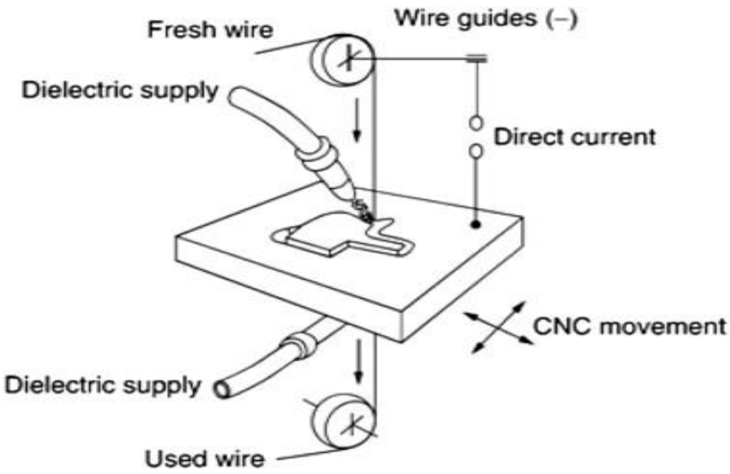

Figure 1. Mechanism of Wire cut EDM[2]

III. LITERATURE REVIEW

- M.Durairaj (2013) has applied Grey relation theory and Taguchi optimization technique, in order to optimize the cutting parameters in Wire EDM for SS304 material. Optimization had carried out to get minimum value of Kerf width and the best surface quality. The input parameters selected for optimization are gap voltage, wire feed, pulse on time, and pulse off time. Additionally, the analysis of variance (ANOVA) is too useful to identify the most important factor.[3] P. Abinesh (2014) studied that WEDM process parameters can be altered to achieve betterment of Material removal rate (MRR), Surface Roughness (SR) and Electrode Wear. They investigated and optimized the potential process parameters influencing the MRR, SR and Electrode Wear while machining of Titanium alloys using WEDM process. This work involves study of the relation between the various input process parameters like Pulse-on time (Ton), Pulse off time(Toff), Pulse Peak Current(IP), Wire material and Work piece material and process variables. Based on the chosen input parameters and performance measures L-16 orthogonal array is selected to optimize the best suited values for machining for Titanium alloys by WEDM.[4] Vijaybabu (2014) describes an optimum cutting parameters for Titanium Grade5 (Ti-6Al-4V) using Wire-cut Electrical Machining Process (WEDM). The response of Volume Material Removal Rate (MRR) and Surface Roughness (Ra) are considered for improving the machining efficiency. A brass wire of 0.25mm diameter was applied as tool electrode to cut the specimen. The Experimentation has been done by using Taguchi's L25 orthogonal array under different conditions like pulse on, pulse off, peak current, wire tension, servo voltage and servo feed settings. Regression equation is developed for the MRR and Ra. The optimum parameters are obtained by using Taguchi method.[5] Milan Kumar Das (2015) have studied of material removal rate (MRR) and surface roughness characteristics of wire electrical discharge machining (WEDM) and the optimization of process parameters based on Taguchi method coupled with grey relational analysis for minimum surface roughness and maximum MRR. Experiments are carried out by utilizing the combination of process parameters viz. discharge current, voltage, pulse on time and pulse off time based on L27 Taguchi orthogonal array (OA). Analysis of variance (ANOVA) carried out and it reveals that current has the maximum contribution in controlling MRR and surface characteristics of

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International Journal of AdvancedResearch in Science, Engineering and Technology
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WEDM.[6] Barun Kumar (2017) has investigate and optimize the process parameters of Wire EDM by Grey relational method. For this, D2 steel work piece has been selected. D2 Die steel is an air hardening, high carbon, and High chromium tool steel. Input process parameters that are taken into consideration are Wire feed rate, Pulse on time, Pulse off time, Peak current, and Servo voltage. Output parameters are Material removal rate, Kerf width, Surface roughness. They used Taguchi methodology of L18 orthogonal array for design of experiment. They concluded that Pulse on time is the greatest effect on MRR and surface roughness compare to other parameters. Servo voltage has little effect on SR and kerf width but it has more effect over MRR.[7]

As in the above mentioned researches and papers we can observe that M-35 HSS with 5% cobalt material is not experimented yet. Taguchi design of experiment is widely used but the Taguchi analysis method is very less preferred so far. So, using this experiment on M-35 HSS with 5% cobalt material optimal process parameter can be determined and significant factor for influencing MRR can also be investigated.

IV. EXPERIMENTAL SETUP

The experimental work is carried out on Wire cut EDM (ELEKTRA MAXICUT 734) machine as shown in the figure 3, of material M-35 HSS with 5% Cobalt by varying machine parameters.

Figure 3. ELEKTRA MAXICUT 734 Wire cut EDM

A. WORKPIECE MATERIAL

M-35 HSS with 5% Cobalt plate has been used as a work piece material for the present experiments. The material has several applications like turning and milling tools for roughing and finishing work, wood working tools, highly stressed cold work tools, tool bits. The work piece material is used of dimension 3.00x19.05x151.00mm

M-35 HSS with 5% Cobalt material is used in turning, milling cutters, broaches and hobs, taps, twist drills, wood working tools, cold work tools. The chemical composition of work material is shown in the Table 1.

Table 1. Chemical Composition of M-35 HSS with 5% Cobalt

Chemical Composition (in %)											
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**V**	**W**	**Co**	**Ni**
M-35	0.85	0.40	0.4	0.3	0.3	4.0	5.25	2.15	6.65	5	-

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International Journal of AdvancedResearch in Science, Engineering and Technology
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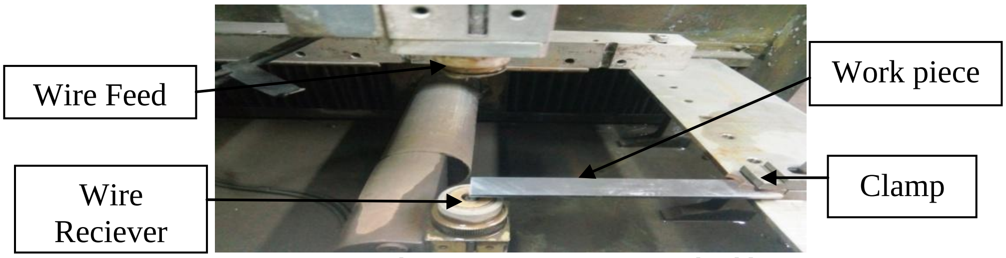

Figure 4. Work piece arrangement on work table

B. SELECTION OF ORTHOGONAL ARRAY AND PARAMETER ASSIGNMENT

For the present work four process parameter are selected as pulse on time (T_{on}), pulse off time (T_{off}), peak current (I_p), spark voltage (S_v) each at three levels have been decided. To find he true behaviour of response factor these parameter are considered at three levels shown in Table 2.

Table 2: Process Parameter and their Levels

Parameter	Symbol	Unit	Level		
			Level 1	level 2	Level 3
Pulse on time	Ton	µs	4	5	6
Pulse off time	Toff	µs	3	4	5
Servo voltage	Sv	V	70	75	80
Peak current	Ip	A	2	3	4

Other then the varying process parameters we have some parameters which are fixed throughout the experiment. These are shown in Table 3.

Table 3: Fixed Parameters

Parameter	Fixed value
Cutting tool	Brass coated wire
Diameter of wire	0.25mm
Dielectric fluid	Di-ionised water
Conductivity of dielectric	40mho
wire speed	5 m/min
Dielectric flow	40 lit/min
Wire tension	9.6N

In the present experiment there are three levels and four factors (process parameter). It mean the total number of experiments become 81 (3^4). The design of orthogonal array is formed for OA L_9 (3^4) using Mintab18 software. This software has directly given the best fit L_9 experiment is reduced to nine instead of eighty one. Table 4 shows the Taguchi orthogonal array L_9, using this values experimentation is performed.

Table 4: Taguchi Orthogonal Array L9

Ton	Toff	Sv	Ip
4	3	70	2
4	4	75	3
4	5	80	4
5	3	75	4

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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5	4	80	2
5	5	70	3
6	3	80	3
6	4	70	4
6	5	75	2

V. RESULT & DISCUSSIONS

A. Experiment for MRR

The experiment is carried out for MRR as response factor with respect to the parameters formed in Taguchi orthogonal array in Table 4. The results for MRR is determined are shown in the Table 5

Table 5: Result table for MRR

Ton	Toff	Sv	Ip	MRR
4	3	70	2	0.321
4	4	75	3	0.38
4	5	80	4	0.448
5	3	75	4	0.494
5	4	80	2	0.353
5	5	70	3	0.451
6	3	80	3	0.477
6	4	70	4	0.501
6	5	75	2	0.38

B. Analysis

For the response factor (MRR) determined in Table 5; Taguchi analysis is carried out and mean and signal to noise ratio is formed. The values of signal to noise ratio and mean for MRR is determine using Minitab 18 software. For material removal rate (MRR) whose larger-is-better for work optimisation work. The S/N ratio is calculated by the logarithmic transformation of loss function as in the Eq (1)

$$\text{S/N ratio} = -10 \log_{10} [\ 1/n \sum^{n}_{i=1} 1/y_i^2] \ ....\text{Eq}(1)$$

Table 6: Value of S/N ratio and Mean for MRR

Ton	Toff	Sv	Ip	MRR		
				MRR*	S/N ratio	MEAN
4	3	70	2	0.321	-9.8698994	0.321
4	4	75	3	0.380	-8.4043281	0.380
4	5	80	4	0.448	-6.9744397	0.448
5	3	75	4	0.494	-6.125461	0.494
5	4	80	2	0.353	-9.0445059	0.353
5	5	70	3	0.451	-6.9164692	0.451
6	3	80	3	0.477	-6.4296324	0.477
6	4	70	4	0.501	-6.0032455	0.501
6	5	75	2	0.380	-8.4043281	0.380

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

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C. Response Table

For three levels of parameters after conducting the analysis using Taguchi analysis in Minitab 18 software we have obtained response table for Signal to noise ratio and mean values for process parameter for each level with loss function representing larger-is-better as higher value of MRR is significant for or result. Table 7 and Table 8 shows the response table for S/N ratio and mean respectively.

Table 7: Response Table for Signal to Noise Ratios

Level	Ton	Toff	Sv	Ip
1	-8.416	-7.475	-7.597	-9.106
2	-7.362	-7.817	-7.645	-7.25
3	-6.946	-7.432	-7.483	-6.368
Delta	1.47	0.386	0.162	2.739
Rank	2	3	4	1

Table 8: Response Table for Means

Level	Ton	Toff	Sv	Ip
1	0.3068	0.3152	0.3208	0.3052
2	0.3213	0.3219	0.31	0.3147
3	0.3236	0.3146	0.3209	0.3318
Delta	0.0168	0.0073	0.0109	0.0266
Rank	2	4	3	1

D. Graphs for mean and SN ratio data

Referring to the response tables of parameter for MRR; for each level and parameter graphs are plotted which shows the effect of mean values of parameter on MRR also the effect of noise on MRR.

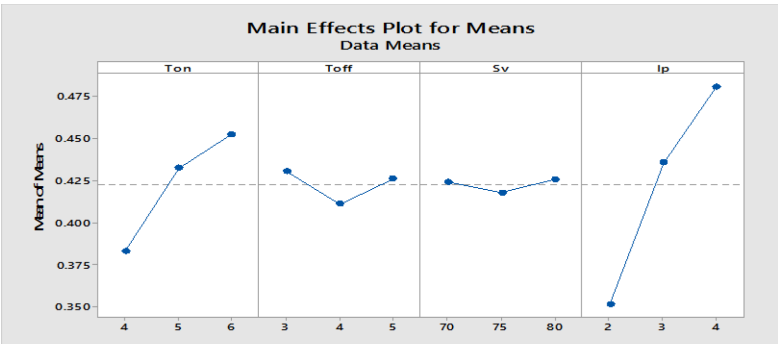

Figure 5. Main effect plot for mean for MRR

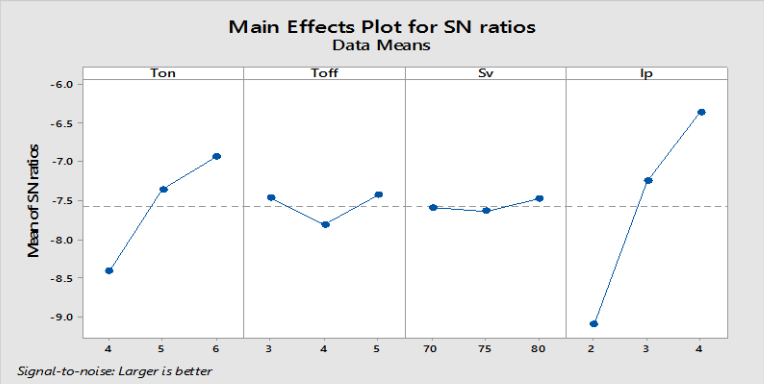

Figure 6. Main Effect plot for S/N ratio for MRR

E. RESULT

Figure 5 and 6 shows the graphs for mean and S/N ratio for MRR. As the graph denotes the larger-is-better for MRR, Table 8 shows the optimal parameter for material removal rate for M-35 HSS with 5% Cobalt material.

Table 8: Optimal parameter for MRR

Pulse on time	6µs
Pulse off time	5µs
Servo voltage	75V
Peak current	4A

VI. CONCLUSION

This research work has presented an investigation on the optimisation and the effect of response parameter on the MRR in Wire cut EDM for M-35 HSS with 5% Cobalt material. With the use of Taguchi analysis we have determine the level of importance of machining parameters on the MRR. According to Taguchi analysis for MRR observing the signal to noise ratio response Table 7 Peak current (I_p) is the most significant factor because it is having Rank 1 then having Rank 2 of Pulse on time (T_{on}) and Rank 3 for pulse off time (T_{off}) and Rank 4 Servo voltage (S_v) are less effective factors in the case of MRR. And predicted optimal setting of process parameter is shown in Table 8.

VII. ACKNOWLEDGEMENT

We are glad to thank persons and institutions who directly or indirectly supported us to complete our paper. We would like to thank our institute Rajasthan Institute of Engineering and Technology, Jaipur, India for providing this platform. We take immense pleasure in thanking Mr. Rakesh Joshi, Instructor, MSME, Jaipur, India who has supported a lot in performing experiments. We also like to thank MSME, Jaipur, India
We wish to thank Ms. Nidhi Kumari, Student, Jagannath University, Jaipur, India for supporting in technical issues and constructing this paper, we thank "anonymous" reviewers for their so-called insights.

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