ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.2

Optimization of Surface Roughness Parameters for Cutting in Wire EDM by Taguchi Method on Al 6063

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Abstract:
In advance manufacturing system, Most of industry has a demand to achieve good surface finish and machining of complex shape. Conventional Machine is unable to achieve the desired results. Conventional machining operation reaches their limitation. Now representing experimental work deal with optimization of surface roughness while machining Aluminum 6063 on wire electric discharge machine using molybdenum wire. Taguchi Model optimization technique is used for this study and L9 Orthogonal Array is used for the design of experiment. The input parameter is Peak Current, Pulse on Time, Pulse off Time and Wire Speed. For each experiment surface finish is determined. ANNOVA is also conducted to check the significant factor. The observed result is also validated by conducting confirmation experiments.

Keywords: WEDM, Surface roughness, Taguchi method, Analysis of variance.

I. INTRODUCTION

The electrical discharge machining (EDM), is a thermo-electric non-traditional manufacturing process, which is gaining popularity, since it does not require cutting tools and allows machining involving hard, brittle, thin and Complex geometry. As there is no direct contact between electrode and the work piece in EDM methodology, the Common problems like mechanical stress and vibration problems in machining are eliminated. In electric discharge Machining (EDM), material is removed from the work piece through localized melting and vaporization of material. Electric sparks are generated between two electrodes when the electrodes are held at a small distance from each other in a dielectric medium and a high potential difference is applied across them. Localized regions of high Temperatures are formed due to the sparks occurring between the two electrode surfaces. Work piece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter electrode gap by the dielectric flow in the form of debris particles. It is commonly used for machining of very hard and tough materials such as tool steels, carbides, finishing parts for surgical, automotive and aerospace industries etc. It is used to produce complex shapes and small holes. The schematic representation of EDM is shown in Fig.1.1. It consists of power supply system, work table, dielectric fluid supply system and control system with a servo-mechanism to control the feed rate of the tool holder. In EDM, pulsed power is supplied to the electrodes from a power supply unit. The constant gap is maintained between the tool and the work piece by the proper feed of the tool towards the work piece during machining using servo control system of the tool holder. The material is removed through the erosion caused by the rapid spark discharge between the work piece and tool. The continuous flushing with dielectric fluid takes place in a gap between the work piece and electrode to remove eroded particles from the cutting zone. The tool electrode has the complementary shape of finished component and accurately sinks into the work piece, by which intricate shapes can be easily produced. The various types of materials be machined by EDM.

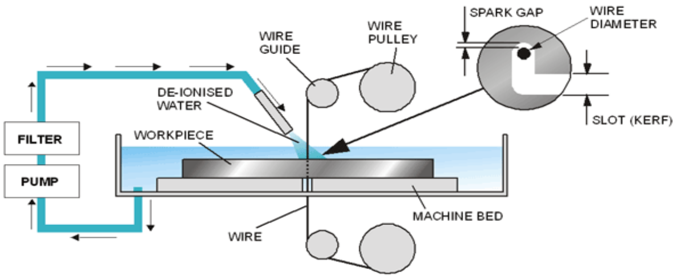

Figure.1. the schematic representation of Electro Discharge Machining

The common metals can be machined by EDM process are tool steels, brass, roll steels, Inconel, Copper, Stainless Steels, hastalloy, titanium, nitronic, aluminum, vasconal-300,WP7V, PCD diamond and other alloys.

II. LITERATURE REVIEW

Wire Electrical Discharge Machining is a controlled machining process which is used to manufacture geometrically intricate shapes with great accuracy and good surface finish that are difficult to machine with the help of conventional machining processes. WEDM is now growing as an important process in various fields; work has been done to use the technology for fabricating micro and major components. EDM, since there is no direct contact between the work piece and the electrode, hence there are no mechanical forces existing between them. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material. In which Prediction of optimal conditions for WEDM of Al 6063/ ZrSiO4(p) MMC, an attempt has been made to machine Al 6063/ ZrSiO4(p) (5%) metal matrix composite using wire electric discharge machining. The objective is to investigate the influence of process parameters namely pulse on time, pulse off time, peak current and servo voltage on cutting rate (1). Optimization of surface roughness while machining High Carbon High Chromium Steel on WEDM using Brass Wire. Taguchi single optimization technique is used (2).An effect of process parameters on surface roughness and kerf width on aluminum and mild steel are investigated and single optimization Taguchi Method is used for process parameter optimization(3). An attempt has been made to optimize the machining conditions for surface roughness based on (L9 Orthogonal Array) Taguchi methodology. Experiments were carried out under varying pulse-on-time, pulse-off-time, peak current, and wire feed. An orthogonal array, the signal-to-noise (S/N) ratio, and the analysis of variance (ANOVA) were employed to the study the surface roughness in the WEDM of AISI D3 Steel (4). Titanium alloys are some of the recently developed advanced materials having excellent mechanical property including high strength to weight ratio and are finding extensive applications in many industries including aerospace industries .But these alloys have poor machinability. Certain non conventional machining technique has been found to be useful in machining these alloys. (5)

III. DESIGN OF EXPERIMENTAL DETAILS:

3.1: Material and methods-

In this present work we have to taking Al 6063 as working material, this material is cut with dimension of 20mm X 20mm X 30mm. for experimentation. The experiments were performed using ELECTRONICA DK 7782Boama WEDM machine tool. The Wire cut Electric Discharge Machine usually consists of a machine tool in the form of electrode which is generally as a Molybdenum wire, a power supply unit which is generally delivering power to operate machine and flushing unit work as to escaping out the cutting debries. Wire travels through the work piece from upper and lower wire guides. In wire-cut EDM process the spark is generated between continuously travelling molybdenum wire (0.25 mm diameter) and work piece. Aluminum alloy 6063 consists the following composition which is as- (0.3% Si, 0.5% Cu, 3.0% Mg, 5.00% Zn and Al remainder).

Table.1. Chemical composition of Al 6063 (wt %)

Material	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other
Al 6063	97.5	0.6	0.35	0.1	0.1	0.9	0.1	0.1	0.1	0.15

Experiments were performed on ELECTRONICA DK 7782Boama CNC wire cut electrical discharge machine to study the material removal rate and surface roughness at different setting of Pulse-on time (Ton), Pulse-off time (Toff), peak current (IP), wire feed (WF) . Performing a series of experiments, making measurements after every experiment so that analysis of observed data helps to decide what to do next "Which parameters should be varied and by how much". It is therefore necessary to conduct pilot experimentation or trial experimentation before the final process parameters ranges are decided.

Table.2. Machine Setting used in the Experiment-

S.N.	Parameter	Unit Level	L1	L2	L3
1	Pulse on time	µs	20	21	22
2	Pulse off time	µs	32	28	24
3	Peak current	A	4	5	6
4	Wire Speed	Mm/min	2	1	0

Figure.2. Working zone of Electro Discharge Machining

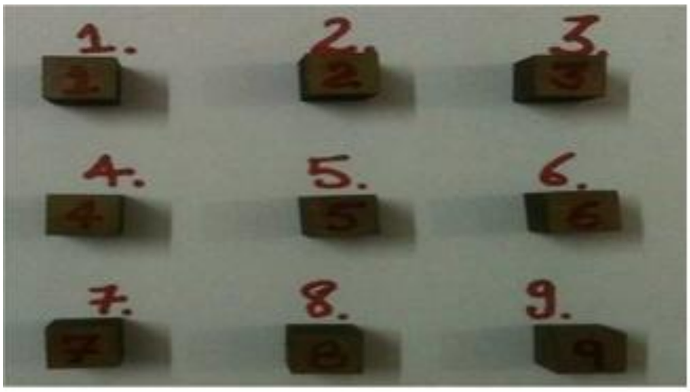

Figure.3. Schematic View of different job (Cutting Work piece)

3.2 Experimental design based on Taguchi Method-

Taguchi proposed to acquire the characteristic data by using orthogonal arrays, and to analyze the performance measure from data to decide the optimal process parameters. The designed matrix of input parameters with output parameters such as surface roughness for aluminum is shown in table-

Table.3. Machine Setting used in the Experiment-

Exp. No	Ton	Toff	IP	Wire Speed	Surface Roughness (µm)
1	20	32	4	2	6.21
2	20	28	5	1	5.91
3	20	24	6	0	6.20
4	21	32	5	0	6.81
5	21	28	6	2	6.75
6	21	24	4	1	6.32
7	22	32	6	1	5.64
8	22	28	4	0	5.91
9	22	24	5	2	6.21

IV. RESULT AND DISCUSSION-

4.1: Effect of input parameter on the surface roughness of Aluminum-

Total input energy transported between wire and work piece is distributed into three main components namely wire, work piece and gap between them. The energy loss comprises heat carried away by the debris by conduction and heat loss due to convection and radiation. The maximum MRR was obtained for cutting of Al 6063 than RHA steel. The reason may be due to lower melting point. Heat of vaporization and thermal conductivity were found to be important characteristics of the material for ascertaining. MRR. Reduction in MRR is attributed to larger heat capacity and thermal conductivity

4.2-Taguchi Design for Experiment- .We have taken three level and four input parameter with the help of these parameters we make an orthogonal array(L9 array) and trying to optimize the following parameter which is as-

Table.4. Response Table for SN ratio and Mean of Surface roughness

S. N.	Ton	Toff	Ip	Wire speed	Avg SR	SNR	MEAN
1	20	32	4	2	6.21	-15.8618	6.21
2	20	28	5	1	5.91	-15.4317	5.91
3	20	24	6	0	6.20	-15.8478	6.20
4	21	32	5	0	6.81	-16.6629	6.81
5	21	28	6	2	6.75	-16.5861	6.75
6	21	24	4	1	6.32	-16.0143	6.32
7	22	32	6	1	5.64	-15.0256	5.64
8	22	28	4	0	5.91	-15.4317	5.91
9	22	24	5	2	6.21	-15.8618	6.21

The experimental results are collected for surface roughness and 9 experiments were conducted using Taguchi (L9) experimental design methodology and there are two replicates for each experiment to obtain S/N values. In the present study all the designs, plots and analysis have been carried out using Minitab statistical software. Lower amount of surface roughness show the high productivity of Wire EDM. Therefore, small the better are applied to calculate the S/N ratio of surface roughness respectively. The optimal machining performance for Surface Roughness was obtained as 22 µs pulse-on time (Level 3), 28 µs pulse-off time (Level 2), 5 A peak current (Level 1) and 1(Normal)

Table.5. Response Table for Means Surface Roughness

Level	Pulse on time	Pulse off time	Peak current	Wire speed
1	6.107	6.243	6.147	6.307
2	6.627	6.190	6.310	5.957
3	5.920	6.220	6.197	6.390
Delta	0.707	0.053	0.163	0.433
Rank	1	4	3	2

Wire speed (Level 3) settings that give the minimum SR. Fig. 4.1 shows the effect of machining parameters on the SR. That surface roughness increases with the increase of pulse on time, and peak current and decreases with increase in pulse off time, and wire speed. The discharge energy increases with the pulse on time and peak current and larger discharge energy produces a larger crater, causing a larger surface roughness value on the work piece. As the pulse off time decreases, the number of discharges increases which causes poor surface accuracy.

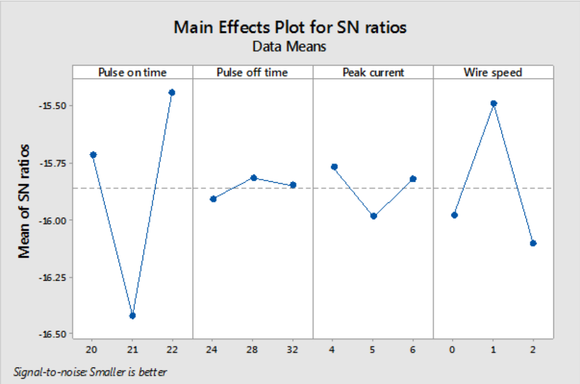

Figure.4. Main effect plot for SN ratios for Surface roughness

4.3-Calculation of mean S/N ratio for Surface Roughness –

Table.6. Analysis of Variance by ANOVA for Surface roughness

Source	DF	Adj SS	Adj MS	F-Value	% Contribution
Pulse on time	2	0.80462	0.402311	*	68.87
Pulse off time	2	0.00429	0.002144	*	0.36
Peak current	2	0.04202	0.021011	*	3.59
Wire speed	2	0.31722	0.158611	*	27.15
Error	0	*	*		
Total	8	1.16816			

4.4- Calculation for ANOVA (CONFIRMATION EXPERIMENT)–

Means of each level of Ton are as follows:-

$$\bar{A}1 = \frac{6.21+5.91+6.20}{3} = 6.1066$$

$$\bar{A}2 = \frac{6.81+6.75+6.32}{3} = 6.6266$$

$$\bar{A}3 = \frac{5.64+5.91+6.21}{3} = 5.920$$

Mean of Means of each level of Ton is given as follows:

$$\bar{A} = \frac{(\bar{A}1+\bar{A}2+\bar{A}3)}{3} = 6.2177$$

Sum of Square for Ton is as follows:

$$Sum\ of\ Square = 3\left[(\bar{A}1-\bar{A})^2+(\bar{A}2-\bar{A})^2+(\bar{A}3-\bar{A})^2\right]$$

$$SS\ of\ Ton = 3\left[(6.1066-6.2177)^2+(6.6266-6.2177)^2+(5.920-6.2177)^2\right]$$

SS of Ton = 0.81000

$$AdjMS = \frac{Sumofsquare}{DegreeofFreedom}$$

$$Adj\ MS\ of\ Ton = \frac{0.81000}{2} = 0.4100$$

$$Percentage\ Contribution = \frac{sumofsquare}{TotalSumofSquare}$$

$$Percentage\ Contribution\ of\ Ton = (0.81000)/(1.16816) = 0.69\%$$

V. CONCLUSION

This paper described the optimization of the WEDM process using parametric design of Taguchi methodology. It was observed that the Taguchi's parameter design is a simple, systematic, reliable, and more efficient tool for optimization of the machining parameters. The effect of various machining parameter such as pulse-on time, pulse off time, peak current and wire speed has been studied though machining of Al 6063. It has identified that the pulse on time and wire speed for minimum surface roughness of work piece have influenced more than the other parameters considered in this study.

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