International Journal of Advanced Mechanical Engineering.
ISSN 2250-3234 Volume 8, Number 1 (2018), pp. 127-136

http://www.ripublication.com

Effect of Process Parameters on Surface Roughness of HSS M35 in Wire-EDM during Taper Cutting

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Abstract:

Wire-electrical- discharge machining (WEDM) is a upgraded electro- discharge machining (EDM) and has been widely used for quite a while cutting punches, dies, shaped pockets and other machine parts on conductive materials. The WEDM procedure is especially appropriate for machining hard materials and additionally complex shapes. The primary objective of the present work is to explore the impacts of different WEDM process parameters on the machining quality and to acquire the ideal sets of process parameters like Part Thickness, Taper Angle, Pulse-ON time, Pulse-OFF time, Wire feed, Wire Tension and Servo Voltage Gap are studied during taper cutting on High Speed Steel (HSS) M 35 by conducting an analysis using L27 orthogonal array. The results got from the experimental runs were investigated by utilizing Minitab17 software. ANOVA for S/N proportions was done to investigate the most contributing process parameters influencing on Surface Roughness (R_a). The results have demonstrated that the improvement in the average surface finish is acquired while machining during taper cutting.

Keywords: Wire-EDM, Taper Cutting, Surface Roughness, ANOVA, HSS M35

I. INTRODUCTION:

In manufacturing industries machining of hard-to-machine materials and complex profiles with high surface finishing come to be a task. As the world advances techniques in the subject of space studies, missiles, air crafts industry, complex profile components have to machine as in line with the requirement of the reason it is used. In recent years, many new hard-to-machine materials were evolved, which can be machined most effectively with unconventional machining methods. WEDM process is an extensively accepted non-conventional manufacturing method in industries. Although it's miles first brought to the manufacturing enterprise in the late 1960s, its reputation is swiftly increasing in the 1970s, when Computer Numerical Control (CNC) machine are into integrated into WEDM.

Wire Electrical Discharge Machining (WEDM) is an electro thermal manufacturing procedure wherein a skinny single strand metallic wire at the side of De-ionized water (used to conduct electricity) lets in the wire to cut through metal through the use of heat from electric sparks. Due to the inherent properties of the process, wire EDM can easily cut complicated components and precision components out of tough conductive materials [1]. The following Figure 1 suggests the Schematic diagram of Wire-EDM reducing procedure. The commonplace parameters are diagnosed from the preceding studies works, Pulse-ON time, Pulse-OFF time, Wire feed, Wire Tension, Pulse Duration, Flushing pressure and Servo Voltage Gap. Very much less of researches work cope with overall performance assessment in taper cutting using WEDM procedure.

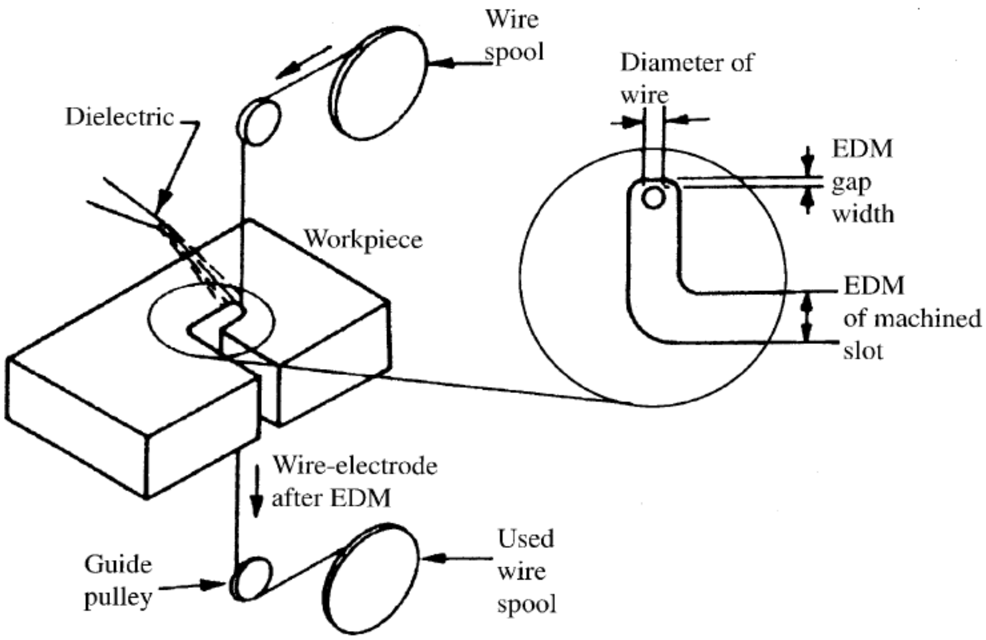

Figure 1: Schematic Diagram of Wire EDM Cutting Process

A. Taper cutting using WEDM process

Taper Cutting is a beneficial application of the wire electric discharge machining process used for the manufacturing of components with complex geometry together with extrusion and manufacture the dies during taper cutting, for taper cutting the wire guides are deformation ensuing in deviations in the inclination angle of machined elements. The primary issues of the tool engineers are dimensional errors and loss of tolerances encountered at time of taper cutting. Generally, it's far difficult to reach curved surfaces repeatedly used for molds and dies the use of traditional strategies as well as straight cutting in WEDM technique. Taper cutting is a completely unique application of the wire electrical discharge machining technique used for production of difficult to machine for complex shapes, tight corners, deep slots and features with a couple of angles used in the aerospace and defense applications. Taper angle is another most important process parameter for taper cutting in WEDM. However, inside the manufacturing of merchandise with taper or draft angles, the WEDM is ready with four interpolated axes: X and Y for the horizontal motion of the system table and U and V for the horizontal motion of the higher guide with respect to the lower guide [2]. Hence, the taper angle is get through applying a relative motion among the higher and lower guides as shown in Figure 2.

Taguchi techniques are statistical methods developed by means of Genichi Taguchi to improve the Quality [3-6], it's miles an effective device for the parameter layout of the overall performance characteristics has been used to decide optimum machining parameters for minimization of Surface roughness in WEDM. The relative effect of the different factors can be acquired by means of the decomposition of variance, that is generally called analysis of variance (ANOVA) [7-8]. In this present work surface roughness is taken as a response parameter.

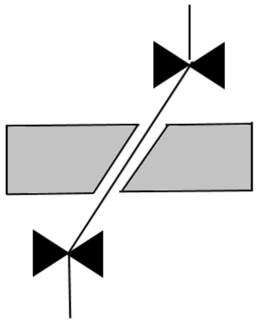

Figure 2: Taper Angle

B. Objectives of the present work

To study the effect of individual processes parameters (Part Thickness, Taper Angle, Pulse-ON time, Pulse-OFF time, Wire feed, Wire Tension and Servo Voltage Gap) on Surface roughness and experiments have been carried out using Taguchi’s L27 Orthogonal Array (OA) experimental design which consists of 27 combinations of seven process parameters, varied in three discrete levels. Optimize the process parameters in order to improve Surface roughness by using DOE and Taguchi ANOVA technique.

II. EXPERIMENTAL SETUP

All the experiments have been conducted on Epluse inside, High-Speed CNC Wire cut EDM manufactured by Electronica Machine Tools Ltd shown in figure 3. The wire used was Bras wire of diameter 0.25mm.

Figure 3: Epluse inside Wire-EDM

The Brass wire was coated with zinc and is known as “stratified Brass wire”. Dielectric fluid used is Deionized water. Surface Roughness Tester used to measure the surface roughness. In the present work to study the impacts of different WEDM process parameters on the machining quality and to acquire the ideal sets of process parameters like Part Thickness, Taper Angle, Pulse-ON time, Pulse-OFF time, Wire feed, Wire Tension and Servo Voltage Gap on surface roughness during taper cutting on High Speed Steel (HSS) M 35 by conducting an analysis using L27 orthogonal array.

III. METHODOLOGY

For optimization of Wire-EDM process parameters the following methodology is followed:

1. Selection of process parameters and their levels.
2. Selection of quality characteristics for each response characteristic.
3. Taguchi Design of Experiments.
4. Experimentation as per the Taguchi DOE.
5. Taguchi analysis and AVOVA for S/N ratio to obtain optimal process parameters, predicted values and contribution of each process parameters.
6. Determining the results at optimum condition.
7. Confirmation of experiments.

The selected processes parameters and their levels are tabulated in table 1, and the selected Taguchi L27 orthogonal array layout with selected process parameters are tabulated is table 2.

Table 1: Selected process parameters and their levels

Process Parameter	Symbol	Unit	Level		
			I	II	III
Part Thickness	PT	mm	11	12	13
Taper Angle	TA	Degree	6	8	10
Pulse-ON time	T_{on}	μ sec	115	120	125
Pulse-OFF time	T_{OFF}	μ sec	53	58	63
Wire feed	WF	m/min	2	3	4
Wire tension	WT	G	6	8	10
Servo Gap Voltage	V	Volts	20	30	40

IV. RESULTS AND DISCUSIONS

The S/N ratios, ANOVA for Surface roughness are carried out using the software MINITAB 17.0. The optimal parameters for surface roughness using Taguchi methods are calculated using the ANOVA analysis. The level with higher delta value (higher S/N- lower S/N) is treated as optimal compared with the other two. In the present analysis, optimal parameters for Surface roughness is Smaller- the-better are shown in the table 3. Response Table for S/N Ratios for MRR is shown in table 4.

Optimal parameters from the table 4, by Taguchi design for Surface Roughness are Part Thickness (PT) = 20mm, Taper Angle (TA) = 6^o, Pulse-ON time (T_{ON}) = 125 µsec, Pulse-OFF time (T_{OFF}) = 63 µsec, Wire Feed (WF) = 2m/sec, Wire Tension (WT) = 6G and Servo Voltage Gap (V) = 20V. From the table 5, S/N ratio plots are plotted to study the effect of each level on the MRR are shown in the figure 5.

From the ANOVA table 5, the most significant factors that affect the Surface Roughness are in ascending order are Taper Angle (TA), Wire Feed (WF), Wire Tension (WT) Pulse-ON time (T_{ON}), Part Thickness (PT), Pulse-OFF time (T_{OFF}) and Servo Voltage Gap (V) respectively based on the percentage of contribution they are providing for the response Surface Roughness. From the above table S/N ratio plots are plotted to study the effect of each level on the R_a are shown in the figure 4.

Table 2: Design Layout for conducting Experiments

Exp. No	**PT**	**TA**	**T_{on}**	**T_{OFF}**	**WF**	**WT**	**V**
1	20	6	120	53	2	6	20
2	20	6	120	53	3	8	30
3	20	6	120	53	4	10	40
4	20	8	125	58	2	6	20
5	20	8	125	58	3	8	30
6	20	8	125	58	4	10	40
7	20	10	130	63	2	6	20
8	20	10	130	63	3	8	30
9	20	10	130	63	4	10	40
10	25	6	125	63	2	8	40
11	25	6	125	63	3	10	20
12	25	6	125	63	4	6	30
13	25	8	130	53	2	8	40
14	25	8	130	53	3	10	20
15	25	8	130	53	4	6	30
16	25	10	120	58	2	8	40
17	25	10	120	58	3	10	20
18	25	10	120	58	4	6	30
19	30	6	130	58	2	10	30
20	30	6	130	58	3	6	40
21	30	6	130	58	4	8	20
22	30	8	120	63	2	10	30
23	30	8	120	63	3	6	40
24	30	8	120	63	4	8	20
25	30	10	125	53	2	10	30
26	30	10	125	53	3	6	40
27	30	10	125	53	4	8	20

Table 3: Processes Responses and their corresponding S/N ratios

Exp. No	**R_a**	**S/N Ratio**	**Exp. No**	**R_a**	**S/N Ratio**
1	2.72	-8.69138	15	3.76	-11.5038
2	2.79	-8.91208	16	3.03	-9.62885
3	3.11	-9.85521	17	3.19	-10.0758
4	2.71	-8.65939	18	3.78	-11.5498
5	2.69	-8.59505	19	2.86	-9.12732
6	3.19	-10.0758	20	3.24	-10.2109
7	3.21	-10.1301	21	3.07	-9.74277
8	3.39	-10.604	22	3.02	-9.60014
9	3.43	-10.7059	23	3.31	-10.3966
10	2.38	-7.53154	24	3.05	-9.686
11	2.62	-8.36603	25	3.32	-10.4228
12	3.32	-10.4228	26	3.61	-11.1501
13	3.14	-9.93859	27	3.52	-10.9309
14	3.23	-10.1841			

Table 4: Response Table for Signal to Noise Ratios Larger is better (MRR)

Level	PT	TA	T_{ON}	T_{OFF}	WF	WT	V
1	-9.581	-9.207	-9.822	-10.177	-9.303	-10.302	-9.607
2	-9.911	-9.849	-9.573	-9.741	-9.833	-9.508	-10.082
3	-10.141	-10.578	-10.239	-9.716	-10.497	-9.824	-9.944
Delta	0.560	1.371	0.666	0.461	1.194	0.794	0.475
Rank	5	1	4	7	2	3	6

Table 5: Results of ANOVA for MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PT	2	1.426	1.426	0.71280	7.88	0.007
TA	2	8.469	8.469	4.23431	46.82	0.000
Ton	2	2.038	2.038	1.01879	11.27	0.002
TOFF	2	1.208	1.208	0.60423	6.68	0.011
WF	2	6.439	6.439	3.21941	35.60	0.000
WT	2	2.876	2.876	1.43782	15.90	0.000
V	2	1.072	1.072	0.53622	5.93	0.016
Residual Error	12	1.085	1.085	0.09043		
Total	26	24.612				

S = 0.3007   R-Sq = 95.6%   R-Sq(adj) = 90.4%

A. Predicted Surface Roughness:

μ (predicted S/N ratio) =Y+ (PT1-Y) + (TA1- Y) + (TON2- Y) + (TOFF3- Y) + (WF1- Y) + (WT2-Y) + (V1 –Y)

Where Y= Average of S/N ratio Values for Surface roughness

$\mu = -9.877 + ((-9.581) - (-9.877)) + ((-9.207) - (-9.877)) + ((-9.573) - (-9.877)) + ((-9.716) - (-9.877)) + ((-9.303) - (-9.877)) + ((-9.508) - (-9.877)) + ((-9.607) - (-9.877))$

$\mu = -7.234$ SB

For Smaller - the -Better

S/N ratio = -10 log (MSD)

$-7.234 = -10 \log (R_a)^2$

$R_a = 2.592$ µm (predicted value).

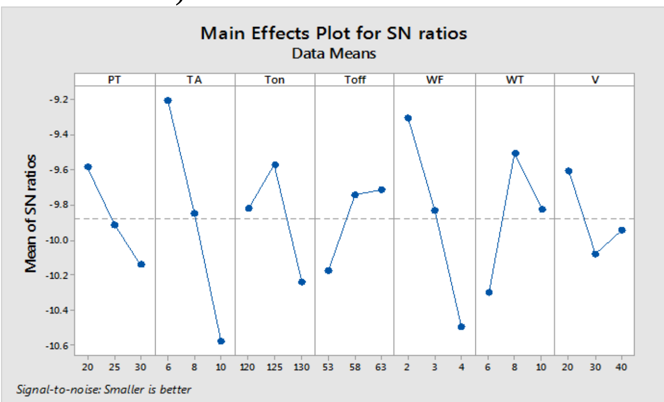

Figure 4. Main Effects Plot for SN ratios

Interestingly the obtained optimal process parameters are not in the Taguchi design, so a confirmatory test is conducted by the obtained optimal parameters and it is observed that better Surface roughness is obtained. Table 6 shows the process responses at obtained optimal process parameter levels.

Table 6: Results of the confirmation experiment

Optimal Machining Parameter		
Level	Surface roughness (Predicted)	Surface roughness (Experimental)
PT1, TA1, TON2, TOFF3, WF1, WT2 and V1	2.592µm	2.616µm

V. CONCLUSIONS

Experiments are conducted to optimize the process parameters during taper cutting High Speed Steel (HSS) M 35 on epluse inside wire EDM using brass wire as electrode. Based on the results obtained and discussion made in the earlier chapters the following conclusions are drawn:

- Increase in Part Thickness, Taper Angle and Wire Feed causes surface Roughness will increases continuously.
- Decrease in Pulse off Time causes surface roughness decreases continuously
- Similarly Pulse ON Time Level-II, Wire Tension is Level- II and Servo Voltage Gap is Level-I are Optimized levels

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