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Kerf width analysis for EN19 material using wire cut EDM with Taguchi design of experiment method

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Abstract: *Wire cut EDM (WEDM) is a Non conventional manufacturing process in which material is removed by localized heating and melting. It is discrete spark generation method applicable for hard and difficult to machine materials.The accuracy and ease for complex contour leads the process very favourite in die application. In this paper Kerf width analysis for EN19 material is carried out using Taguchi design of experiment method. Experiments are carried out using L27 Orthogonal array by varying Material Thickness, pulse on time, Pulse Off time, Flushing Pressure, Wire Tension and Servo voltage. ANOVA carried out for identifies significant parameters for kerf width. Kerf width affected by machining parameters, which is important for machining accuracy and other output response viz MRR and Surface roughness. Analysis help to identify significant parameters for kerf. A set of optimum parameters and rank order identified using ANOVA.*

Keywords*-WEDM, PULSE ON TIME, PULSE OFF TIME, S/N RATIO*

I. INTRODUCTION

WEDM is a non-conventional thermo electric material removal method for conductive materials to cut intricate shapes and profiles with a thin wire electrode. The electrode is a thin wire of a diameter 0.05 – 0.25 mm copper or brass coated with molybdenum. As wire feeds from reel to reel, material is eroded from work material by a series of discrete sparks occurring between the work piece and the wire under the presence of dielectric fluid which is continuously fed to the machining zone [1]. The WEDM process makes use of electrical energy generating a channel of plasma between the cathode and anode [2] and turns it into thermal energy at a temperature in the range of 8000–12,000 ºC [3]. When the pulsating direct current power supply occurring between 20,000 and 30,000 Hz is turned off, the plasma channel breaks down. This causes a sudden reduction in temperature allowing circulating dielectric fluid to implore plasma channel and flush molten particles from the pole surfaces in form of microscopic debris [4].Erosion of metals by spark was first reported by Joseph Priesily in 1978, however controlled machining by sparks was first introduced by Lazarenko in Russia in 1944. The first British patent was granted to Rudorff in 1950 [5]. In 1974 D.H. Dulebohn applied optical-line follower system to automatically control shape of component to be machined by WEDM process [6]. By 1975, its popularity was rapidly increasing, as the process and its capabilities were better understood by the industry.

1.1 Working Principle of WEDM

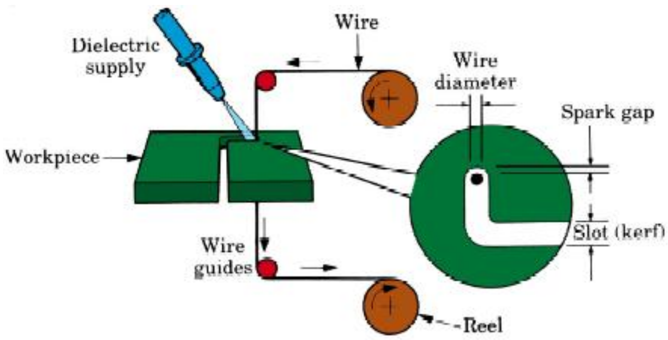


Figure 1.1 Wire electrical discharge machining process

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. When sufficient voltage is applied, the fluid ionizes, a controlled spark precisely erodes a small section of the work piece, 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 solidified liquid at a constant temperature. A DC or AC servo control system maintains a gap from .05 to .075 mm between the wire electrode and the work piece. The servo mechanism prevents the wire electrode from shorting out against the work piece and advances the machine as it cuts the desired shape. Because the wire never touches the work piece, wire EDM is a stress-free cutting operation. WEDM consider as precision manufacturing process. Kerf width is the slot with summation of wire diameter and twice the spark gap.

II. EXPERIMENTAL SETUP

2.1 Material Specification

Wire-cut EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. In this research experiments carried out for EN19 material. EN19 is a Chromium-Molybdenum low alloy steel. This can be used in the toughened condition. EN-19 offers high corrosion resistance, wear strength and high hardness. The chemical composition tested at MET-HEAT ENGINEERS PVT. LTD of the selected work material is shown in Table 2.1

Table 2.1 Chemical composition of EN19

Chemical	% C	% Si	% Mg	% P	% S	% CR	% Mo
Obtained Value	0.430	0.289	0.696	0.038	0.057	1.148	0.234

2.2 Design of experiment based on Taguchi method

In this study parametric analysis carried out by varying six control factors on Ultracut f1 machine of Electronica Pvt. Limited. Molybdenum coated brass wire of 0.25 mm diameter was used. Control factors along with their levels are listed in Table 2.2. During experiments fixed parameters set. As table 2.2. Selection of parameters based on literature survey. the selection of Full factorial design of experiments would require a large no. of runs; Hence Taguchi based design of experiment method was implemented. In Taguchi method Orthogonal Array provides a set of well-balanced experiments, and Taguchi's signal-to-noise. (S/N) ratios, which are logarithmic functions of the desired output, serve as objective functions for optimization. It helps to learn the whole parameter space with a minimum experimental runs. Taguchi replaces the full factorial experiments with a lean, less expensive, faster partial factorial experiment.

Table 2.2 Control parameters and their levels

Machining Process Parameter	Level 1	Level 2	Level 3
Material thickness (mm)	20	30	40
Pulse On Time	110	120	130
Pulse Off Time	40	50	60
Flushing Pressure (Kgf/cm2)	10	12	14
Wire Tension (gms)	660	900	1140
Servo Voltage (volts)	20	30	40

Table 2.3 Fixed Parameters

Fixed Parameter	**Set Value**
Peak current (IP)	12
Pulse Peak Voltage	1
Wire Feed Rate	8
Servo Feed Setting	2100

2.3 Specimen detail

L27 Orthogonal array obtain based on the control factors. Total 27 nos. of experiments has been carried out by travelling electrode 8 mm in linear direction and then cut a piece of 5 mm x 5 mm from Dia. 60 mm EN19 material. Wire feed and Peak current selected as constant. Specimen after machining for each thickness level shown in fig 2.1.

Fig. 2.1 Specimen after Machining: Size - Dia. 60mm and Thickness 40 mm

III. Results and Analysis

Table 3.1 shows the experimental results. Experiments carried out by setting parameters as per orthogonal array and kerf width measured for every run. Kerf width measured with help of profile projector and same verified using software with taking high resolution image. The kerf width measure at three equal distance point and then average of that considered for analysis.

Table 3.1 Experimental result table for Kerf width

ExpNo.	Input Parameters						Output Parameters	
	Mat. Thickness (A)	Pulse on time (B)	Pulse Off time (C)	Flushing Pressure (D)	Wire Tension (E)	Servo voltage (F)	**kerf width (mm)**	**Spark Gap (mm)**
1	20	110	40	10	660	20	0.347	0.049
2	20	110	40	10	900	30	0.373	0.062
3	20	110	40	10	1140	40	0.344	0.047
4	20	120	50	12	660	20	0.315	0.033
5	20	120	50	12	900	30	0.345	0.048
6	20	120	50	12	1140	40	0.369	0.060
7	20	130	60	14	660	20	0.372	0.061
8	20	130	60	14	900	30	0.350	0.050
9	20	130	60	14	1140	40	0.345	0.048
10	30	110	50	14	660	30	0.331	0.041
11	30	110	50	14	900	40	0.374	0.062
12	30	110	50	14	1140	20	0.311	0.031
13	30	120	60	10	660	30	0.381	0.066
14	30	120	60	10	900	40	0.388	0.069
15	30	120	60	10	1140	20	0.343	0.047
16	30	130	40	12	660	30	0.359	0.055
17	30	130	40	12	900	40	0.345	0.048
18	30	130	40	12	1140	20	0.352	0.051
19	40	110	60	12	660	40	0.324	0.037
20	40	110	60	12	900	20	0.345	0.048
21	40	110	60	12	1140	30	0.347	0.049
22	40	120	40	14	660	40	0.324	0.037
23	40	120	40	14	900	20	0.372	0.061
24	40	120	40	14	1140	30	0.368	0.059
25	40	130	50	10	660	40	0.382	0.066
26	40	130	50	10	900	20	0.358	0.054
27	40	130	50	10	1140	30	0.384	0.067

Calculation of Signal to Noise ratio

SN ratio can be calculated based on response requirement. Material removal rate preferred always higher is better and roughness value lower is better. Kerf width is always lower is better [6]. S/N ratio calculated for Higher is better (Eq. 1) and smaller is better (Eq. 2). The analysis carried out on MINITAB 15 software.

$$SN\ for\ Higher\ is\ better = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y1^2}\right] \text{-------------------------- (Eq. 1)}$$

$$SN\ for\ Lower\ is\ better = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}y1^2\right] \text{-------------------------- (Eq. 2)}$$

IV ANOVA ANALYSIS DISCUSSION

Analysis of Variance (ANOVA) is a powerful analyzing tool to identify which are the most significant factors and it's (%) percentage contribution among all control factors for each of machining response. It calculates variations about mean ANOVA results for the response. Based on F-value (Significance factor value) important parameters can be identified. Table 4.1 shows the calculated result for S/N ratio for kerf width and Table 4.2 is ANOVA Table obtained by MiniTab15 software. ANOVA Table contain Degree of freedom (DF), Sum of Squares (SS), Mean squares (MS), Significant Factor ratio (F-Ratio), Probability (P)

Table 4.1 CALCULATION OF S/N RATIO

ExpNo.	Input Parameters						Output Parameters	
	Mat. Thickness (A)	Pulse on time (B)	Pulse Off time (C)	Flushing Pressure (D)	Wire Tension (E)	Servo voltage (F)	**kerf width (mm)**	**S/N RATIO (CALCULATED)**
1	20	110	40	10	660	20	0.347	**9.1934**
2	20	110	40	10	900	30	0.373	**8.5658**
3	20	110	40	10	1140	40	0.344	**9.2688**
4	20	120	50	12	660	20	0.315	**10.0338**
5	20	120	50	12	900	30	0.345	**9.2436**
6	20	120	50	12	1140	40	0.369	**8.6595**
7	20	130	60	14	660	20	0.372	**8.5891**
8	20	130	60	14	900	30	0.350	**9.1186**
9	20	130	60	14	1140	40	0.345	**9.2436**
10	30	110	50	14	660	30	0.331	**9.6034**
11	30	110	50	14	900	40	0.374	**8.5426**
12	30	110	50	14	1140	20	0.311	**10.1448**
13	30	120	60	10	660	30	0.381	**8.3815**
14	30	120	60	10	900	40	0.388	**8.2234**
15	30	120	60	10	1140	20	0.343	**9.2941**
16	30	130	40	12	660	30	0.359	**8.8981**
17	30	130	40	12	900	40	0.345	**9.2436**
18	30	130	40	12	1140	20	0.352	**9.0691**
19	40	110	60	12	660	40	0.324	**9.7891**
20	40	110	60	12	900	20	0.345	**9.2436**
21	40	110	60	12	1140	30	0.347	**9.1934**
22	40	120	40	14	660	40	0.324	**9.7891**
23	40	120	40	14	900	20	0.372	**8.5891**
24	40	120	40	14	1140	30	0.368	**8.6830**
25	40	130	50	10	660	40	0.382	**8.3587**
26	40	130	50	10	900	20	0.358	**8.9223**
27	40	130	50	10	1140	30	0.384	**8.3134**

ANOVA ANALYSIS FOR KERF WIDTH

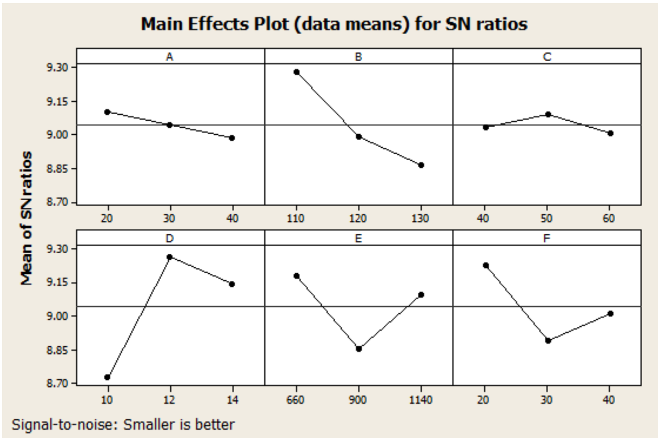
Table 4.2 ANOVA for kerf

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	0.05945	0.05945	0.02973	0.1	0.902
B	2	0.83936	0.83936	0.41968	1.47	0.275
C	2	0.03253	0.03253	0.01627	0.06	0.945

D	2	1.44425	1.44425	0.72213	2.54	0.129
E	2	0.51822	0.51822	0.25911	0.91	0.434
F	2	0.5397	0.5397	0.26985	0.95	0.42
D*E	4	0.9804	0.9804	0.2451	0.86	0.52
Residual Error	10	2.84803	2.84803	0.2848		
Total	26	7.26196				

Table 4.3 Rank order

Level	A	B	C	D	E	F
1	9.102	9.283	9.033	8.725	9.182	9.231
2	9.045	8.989	9.091	9.264	8.855	8.889
3	8.987	8.862	9.009	9.145	9.097	9.013
Delta	0.115	0.421	0.083	0.539	0.327	0.342
Rank	5	2	6	1	4	3



Increasing pulse on time sustain spark for longer period so more thermal energy is generated causing evenly distribute the spark which leads to decrease in kerf. With increase of pulse off and servo voltage the kerf width decreases, this is due to the fact that with the decrease of discharge duration the overcut during discharge also increases as the discharge energy per pulse increases. Increase of wire tension leads kerf width increases but it hasn't much significant effect. Flushing pressure has significant effect on kerf. Flushing pressure helps to remove particle from the gap. Higher the flushing pressure flushed away the particles. In sufficient flushing lead to wire breakage because of obstructing plasma channel.Table 4.3 showsthe rank order for significant parameters. Kerf width is most affected by flushing pressure, pulse on time and servo voltage. Interaction between flushing pressure and wire tension affect also. Pulse off time, material thickness has less significant effect.

V. CONCLUSION

WEDM is a desecrate spark generation method in which process parameters affect over kerf width. Kerf is important parameter for MRR as well as surface roughness. ANOVA Analysis helps to identify the significant parameters. Analysis shows that flushing pressure is most significant parameter for kerf. Rank order obtained with ANOVA as significant parametersorder is Flushing pressure, Pulse On time, Servo voltage, Wire tension, Material thickness and pulse off time.

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