Optimizing The Process Parameters of WEDM For Kerf Width Using Taguchi Technique on ASTM-A681

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Abstract- *The main objectives of this study to investigate and evaluate the effect of different input process parameters (Gap voltage, wire feed rate, pulse on time, pulse off time) on kerf width as response parameters have been considered for Each Experiment. Experimentation was planned as per Taguchi's L16 Orthogonal array during machining of ASTM A681 H13 steel alloy. Brass wire electrode with 0.25mm Diameter was used as tool in the Experiments. Taguchi design methodology will be used for design of experiment and L16 orthogonal array will be used for present study. Maximum MRR is obtained by setting the parameters as Gap voltage 38, Wire Feed 5.5, Pulse On Time 9, Pulse Off Time 7.*

Keywords- ANOVA, ASTM-A681, KERF WIDTH, TAGUCHI, WEDM.

I. INTRODUCTION

In modern mechanical industry, materials of high hardness, toughness and impact resistance are preferred for use. Like these materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including ultrasonic machining, electrochemical machining, electrical discharging machine (EDM) etc. are applied to machine for such difficult machine materials. WEDM process is a thin wire electrode transforms electrical energy to thermal energy used for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials are machined as their hardness and toughness is so high. WEDM is capable of producing a accurate, smooth, corrosion and wear resistant surface. WEDM is considered as a unique adoption of the conventional EDM process, which uses an electrode to initialize the sparking process. In WEDM electrode is of copper, brass or tungsten wire of diameter 0.05-0.30 mm. Thin wire is used for very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. (WEDM) technology has shown tremendously since it was first applied more than 30 years ago.

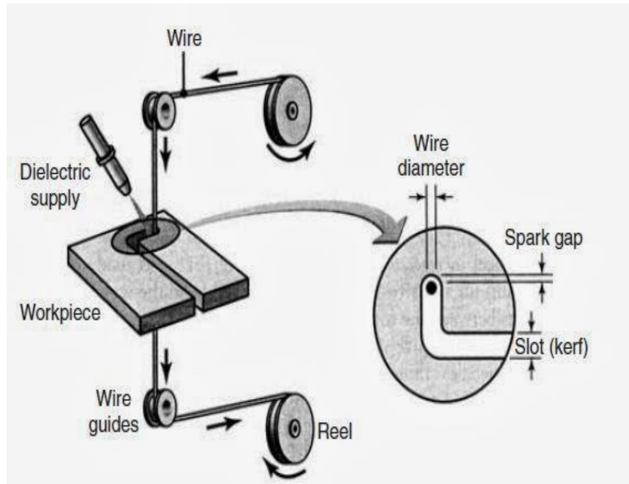


Fig.1 Shows the systematic setup of WEDM.

II. LITERATURE REVIEW

Madic M. et. al 2015 [1] developed mathematical model for establishing relationship between laser cutting parameter such as laser power, cutting speed & gas pressure, and kerf width obtained in $C0_2$ laser cutting of aluminum alloy AlMg3. They further developed second order polynomial model by using experimental data obtained in laser cutting as per full factorial experimental design. Discreete Montecarlo method was used to minimize kerf width.

S. B. Prajapati et.al 2013 [2] In this investigation Wire EDM most progressive non-conventional machining process in mechanical industries. Many parameters affect the performance of Wire EDM. Few of them investigated in this research paper. The effect of process parameter like Pulse ON time, Pulse OFF time, Voltage, Wire Feed and Wire Tension on MRR, SR, Kerf and Gap current were studied by conducting an experiment. Response surface methodology was used to analyze the data for optimization and performance. The AISI A2 tool steel was used as work piece material in the form of square bar.

Gajjar and Desai 2015 [3] investigated the process parameters for surface roughness, kerf width and MRR in wire electric discharge machining of EN -31 tool steel. Taguchi design of experiments was used to conduct the experimentation by varying the process parameters servo voltage, pulse-on-time and pulse-off-time. Grey relational method was used to find the optimal values for surface roughness, kerf width and material removal rate.

Adeel Ikram et.al 2013 [4] This paper reports the effect and optimization of eight control factors on material removal rate (MRR), surface roughness and kerf in wire electrical discharge machining (WEDM) process for tool steel D2. The experimentation was performed under different cutting conditions of wire feed velocity, dielectric pressure, pulse on-time, pulse off-time, open voltage, wire tension and servo voltage by varying the material thickness. Taguchi's L18 orthogonal array was employed for experimental design. Analysis of variance (ANOVA) and signal-to-noise (S/N) ratio were used as statistical analyses to identify the significant control factors and to achieve optimum levels respectively. Additionally, linear regression and additive models were developed for surface roughness, kerf and material removal rate (MRR). Results of the confirmatory experiments were found to be in good agreement with those predicted. It has been found that pulse on-time was the most significant factor affecting the surface roughness, kerf and material removal rate.

III. EXPERIMENTAL SET-UP

It is measured in millimetres (mm). It is the measure of the amount of the material that is wasted during machining and determines the dimensional accuracy of the finishing part. For present experiments kerf width has been measured using Nikon profile projector model 6C as shown in Fig. below available in Metal Tech Engineers which is placed at Gobind Nagar Ambala Cantt. Kerf width is denoted by KW in this report.

Sr. No	Name	Range
1	Magnification	10 X To 500 X
2	Screen Diameter	30 To 0.6 mm.
3	Working distance	60 To 5 mm
4	X-Y-Z Displacement	82 x 62 x 74 mm.
5	Flower area Size	40 x 56 mm.
6	Magnification /Weight	10X/60kg.
7	Accuracy of Magnification	Within ±0.1% of nominal value of each lens Within ± 0.15% when used half reflecting mirror
8	Electrical requirement	Primary current A.C 100V Single phase 50-60 cycle Capacity 150V
9	Light source	70w with specified filament

IV. WORKPIECE MATERIAL SELECTION

The material selected for this dissertation work is ASTM A681 H13 Alloy Steel. Chemical composition of this material is shown in table given below. ASTM A681 H13 has the wide applications in stamping dies, metal cutting tools or any other industries because of its high strength and heavy weight. In general the edge temperature under expected use is an important determine of both composition and required heat treatment.

CHEMICAL	VALUE
Carbon	0.40
Manganese	0.40
Phosphorus	0.03
Sulphur	0.03
Silicon	1.10
Chromium	5.10
Vanadium	0.50
molybdenum	1.30

Density (kg/m^3) – 7750
Specific Gravity - 7.8
Melting Point (Deg F) – 2600
Modulus of Elasticity Tension – 29

V. METHODOLOGY

Taguchi's approach is a method for improving the quality of a product through minimizing the effect of variation without eliminating the causes. Reducing in variation may be the same as increasing in S/N ratio. The S/N ratio can be defined as nominal-the-best, smaller-the-better or larger-the better according to the characteristics of the problem. Since the response is Material removal rate, S/N ratio is defined to be Larger the better. Taguchi's robust design is a simple, systematic and more efficient method to determine optimum or near optimum settings of design parameters. Many researchers have attempted to analyze and optimize a single performance characteristic of a manufacturing process using Taguchi methodology. In this present work, optimization of WEDM operations using Taguchi's robust design methodology with single performance characteristics is proposed. The system involves deciding the best values/levels for the control factors. The signal to noise (S/N) ratio is an ideal metric for the purpose. An important class of design optimization problem requires minimization of the variance while keeping the mean on target. Between the standard deviation and mean, it is typically easy to adjust the mean on target, but reducing the variance is difficult. Therefore, the designer should minimize the variance first and then adjust the mean on target. Among the available control factors most of them should be used to reduce variance. Only one or two control factors are adequate for adjusting the mean on target. The design optimization problem can be solved in two steps:
Step.1 Maximize the S/N ratio. Maximizing this S/N is to maximize the mean and to minimize standard deviation. This is the step of variance reduction.
Step.2 Adjust the mean on target using a control factor that has no effect on S/N ratio. This is the step of adjusting the mean on target.

VI. SELECTION OF CUTTING PARAMETERS

Throughout this dissertation work input parameters considered for Wire cut EDM are machining parameters like as wire feed, gap voltage, pulse on time and pulse off time and output parameters is material removal rate.

Process parameters	Symbols	Units	Levels Selected			
			1	2	3	4
Wire feed	WF	m/min	2.5	5.5	7.5	9.5
Gap Voltage	GV	Volt	38	43	48	53
Pulse on-time	T_{on}	Ms	3	5	7	9
Pulse off-time	T_{off}	µs	3	5	7	9

Sr. No.	Fixed Parameters	Set Value
1	Wire material	Brass (0.25mm)
2	Peak current (IP)	230
3	Flushing pressure (kgf/cm2)	5.5
4	Wire Tension (gms)	550

As per table, L16 orthogonal array of "Taguchi method" has been selected for the experiments design in MINITAB 18.

VII. EXPERIMENTAL RESULTS

Sixteen experiments were performed to find how the output parameter varies with the variation in the input parameters according to the experimental design given by theMINITAB 18.

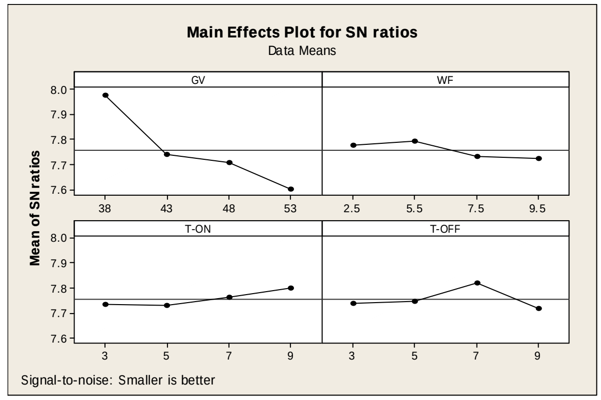
GV	WF	T_{ON}	T_{OFF}	KW	SNRA1	MEAN1
38	2.5	3	3	0.398	8.00234	0.398
38	5.5	5	5	0.400	7.95880	0.400
38	7.5	7	7	0.398	8.00234	0.398
38	9.5	9	9	0.401	7.93711	0.401
43	2.5	5	7	0.408	7.78680	0.408
43	5.5	3	9	0.412	7.70206	0.412
43	7.5	9	3	0.411	7.72316	0.411
43	9.5	7	5	0.410	7.74432	0.410
48	2.5	7	9	0.413	7.68100	0.413
48	5.5	9	7	0.403	7.89390	0.403
48	7.5	3	5	0.415	7.63904	0.415
48	9.5	5	3	0.416	7.61813	0.416
53	2.5	9	5	0.415	7.63904	0.415
53	5.5	7	3	0.416	7.61813	0.416
53	7.5	5	9	0.419	7.55572	0.419
53	9.5	3	7	0.417	7.59728	0.417

LEVEL	GV	WF	T_{ON}	T_{OFF}
1	7.975	7.777	7.735	7.740
2	7.739	7.793	7.730	7.745
3	7.708	7.730	7.761	7.820
4	7.603	7.724	7.798	7.719
Delta	0.373	0.069	0.068	0.101
Rank	1	3	4	2

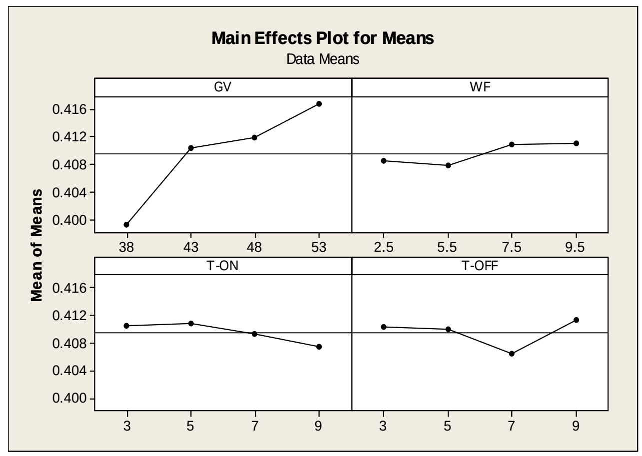
Response Table for Signal to Noise Ratios

LEVEL	GV	WF	T_{ON}	T_{OFF}
1	0.3993	0.4085	0.4105	0.4102
2	0.4102	0.4078	0.4108	0.4100
3	0.4118	0.4108	0.4093	0.4065
4	0.4168	0.4110	0.4075	0.4113
Delta	0.0175	0.0032	0.0032	0.0047
Rank	1	3.5	3.5	2

Response Table for Means



Effect of various factors on SN ratios



Effect of various factors on Means

In the above graphs effects of various factors i.e. gap voltage, wire feed, pulse on time, pulse off time is shown on kerf width, the results of which are discussed below:

1. The first graph of means shows the effect of gap voltage on kerf width. It is shown that with increase in gap voltage, kerf width gradually increases. Value of kerf width is minimum at a gap voltage of 38 volts.
2. The second graph of means shows the effect of wire feed on kerf width. When the gap voltage increases from 2.5 to 5.5 then a positive small decrease shows in kerf width. When it further increases from 5.5 to 7.5 then kerf width increases along the wire feed and again kerf width is increased with a small amount when the wire feed changes from 7.5 to 9.5m/min.
3. In means graph the third graph shows the effect of pulse on time on kerf width. It is clearly shown that with increase in pulse on time, kerf width decreases. When pulse on time increases from 3 to 5 µs, kerf width increases from 0.410 to 0.411mm. When pulse on time again increases from 5 to 9 µs then kerf width continuously decreases from 0.411 to 0.407mm.
4. In means graph the fourth graph indicated the effect of pulse off time on kerf width. It is clearly shown that with

increase in pulse off time, kerf width increases. When pulse off time increases from 3 to 5 µs, kerf width slightly decreases but it continuously decreased along the pulse off time till 7µs. When pulse off time again increases from 7 to 9 µs then kerf width starts increases.

Regression Analysis of Variance for Kerf Width

SOURCE	DF	Adj SS	Adj MS	F-Value	P-Value	%C
GV	3	0.0006530	0.0002177	30.37	0.010	83.29
WF	3	0.0000315	0.0000105	1.47	0.381	04.02
T_{ON}	3	0.0000265	0.0000088	1.23	0.434	03.38
T_{OFF}	3	0.0000515	0.0000172	2.40	0.246	06.56
ERROR	3	0.0000215	0.0000072			02.75
TOTAL	15	0.0007840				

Analysis of Variance for Regression Analysis

From the results of the ANOVA table, it is clear that gap voltage is found to be the most significant factor P-value 0.010 which is less than 0.05 & its contribution to kerf width is 83.29%.

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