ANALYSIS OF PROCESS PARAMETERS OF WIRE EDM ON kerf WIDTH

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Abstract : Wire electrical discharge machining is a non-conventional precision machining process that is widely used in tool and die making industry for the manufacturing of high precision stamping dies, wire drawing dies, sheet metal press dies and extrusion dies. This paper present analysis of process parameters of wire EDM on kerf width of EN-31. Experiments have been performed with three machining variables: pulse-on time, pulse-off time and peak current. Full factorial methodology has been used for planning and designing the experiment. Analysis of variance (ANOVA) is used as statistical analysis to identify the significant control factors. Regression equation has been developed for kerf width. It has been found that pulse-on-time is the most significant factor affecting kerf width.

IndexTerms –
WEDM: Wire Electric Discharge Machining
MRR: Material Removal Rate
ANOVA: Analysis of variance

I. INTRODUCTION

In contemporary manufacturing practice, the demand for harder, tougher and high strength to weight ratio materials is increasing day by day. Other than machinability, shape complexity of the job to be machined, need of automated data transmission, high precision and efficiency during modern manufacturing practice spotlight the research on non-traditional machining process. The rapidly growing demand of better surface finish and greater accuracy especially in tool and die making industry has compelled the researchers to persistently investigate the complex interrelation that exist between the process parameters and desired performance measures of the WEDM process [11]. WEDM is a nontraditional, thermoelectric process which erodes material from the workpiece using a series of discrete sparks between a work and tool electrode separated by a thin film of dielectric fluid (deionised water) and the dielectric is fed continuously to the machining area to flush away the eroded particles [1]. In WEDM cutting, a single-stranded thin wire electrode is fed constantly against the workpiece material through a CNC controlled guidance system. Generally brass and copper wires are used but it was found that the productivity and other characteristics are not up to the mark, so here we use zinc coated wire as several authors found that the coated wire improved the machining process [7]. Figure 1 shows the schematic representation of Wire-EDM process.

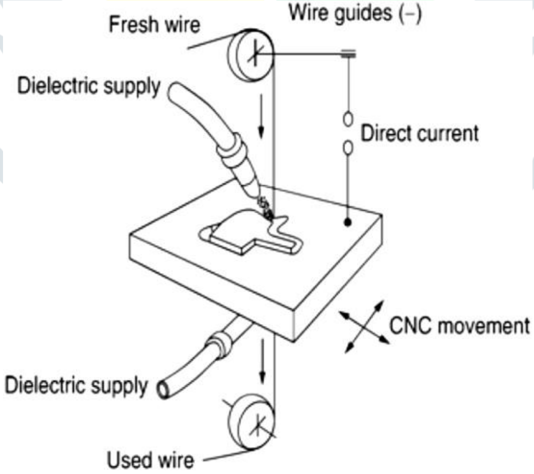

Figure 1 Schematic representation of Wire-EDM process

Amitesh [1] employed Multi-response optimization using grey relational analysis to optimize input parameter of WEDM for WWR, surface integrity and MRR. Linear regression and additive models were developed for surface roughness (SR), Kerf width and material removal rate (MRR). Pulse-on-time is the most significant parameter for SR, Kerf width and MRR. Vikram [2] investigated most significant parameters for SR and MRR using Taguchi orthogonal array L27. A mathematical model is developed by using Response Surface Methodology (RSM). Ravindranath [3] performed multi response optimization of Wire-EDM process parameters for Ballistic grade Aluminum alloy. Confirmation test have been carried out to validate the result obtained by Gray Relation Analysis. Sneha [4] attempted to optimize input parameter on Kerf width, SR and MR. regression equation for all responses are generated using Minitab-17. The investigated output helps to control the kerf, SR, and MRR for the desired application. Shubhajit [5] examined pulse-on-time, pulse-off-time, servo voltage and peak current against SR and optimized for further minimum Ra. ANOVA analysis revealed that Ton is the most significant factor followed by peak current in predicting Ra.
Shrinivas [6] optimizes Wire-EDM parameters for Surface Roughness and Material Removal Rate. The parameters pulse-on-time, peak current and spark gap voltage have shown significant effect on surface roughness and material removal rate. Prashant [7] presented optimization of AISI D3 steel using TM and PCA (Principle component analysis) for multi-objective optimization using S/N ratio obtained from TM. Servo voltage, pulse on time and peak current are the significant parameters. Shubhajit [8] studied for

investigation of surface roughness of Al6061 Hybrid Nano Composites by using parameters pulse-on-time, pulse-off-time, servo voltage and peak current with Taguchi and RSM model. Udaya [9] attempted to develop an appropriate machining strategy for Wire-EDM of hybrid AMC's using 0.25 mm diameter brass wire as the electrode by using parameters such as gap voltage, pulse-on-time, pulse-off-time, wire feed and percentage reinforcement. Hulas Raj [10] investigated the optimum values of machining parameters for attaining economical and competent parameters of Wire-EDM and analyzed the observed results statistically to predict the optimal values for material removal rate and surface roughness. The feasible set of cutting factors which maximizes the MRR has been obtained through statistical analysis using RSM. Adeel Ikram [11] employed Taguchi approach to investigate the effect of wire feed velocity, dielectric pressure, pulse-on-time, open voltage, wire tension and servo voltage by varying material thickness on material removal rate (MRR), surface roughness and kerf width for tool steel D2

II. EXPERIMENTAL WORKS

The experiments were carried out on an Electronica Wire-EDM machine (ELEKTRA SPRINTCUT-AU) machine installed at Indo-German Tool Room, Aurangabad. Figure 2 shows schematic representation of Wire-EDM installed at IGTR.

Figure 2 Schematic representation of Wire-EDM

2.1 Workpiece material

The EN-31 alloy steel has been used as a workpiece material for the present experiments. EN-31 is an excellent high carbon alloy steel which offers a high measure of hardness with compressive strength and abrasion resistance. Chemical composition of EN-31 is shown in Table No.1. EN-31 is quite often used for wear resisting machine constituents and for press instruments.

Table 1 Chemical composition of EN-31

Constituents	C	Mn	Si	S	P	Cr	Ni	Mo	V
% Composition	0.90	0.60	0.20	0.020	0.022	1.30	Ni	-	-

III. TOOL MATERIAL

The electrode has been used for the experiment is a zinc coated brass wire of 0.25 mm diameter whereas de-ionized water used as dielectric. This zinc-coated wire consists of brass wire electroplated with high purity zinc. The high plating accuracy realizes faster machining speed and also provides a better surface finish on the work piece. The finishing process, improved surface roughness and a better machined profile are obtained.

IV. METHODOLOGY

In the present work, the full factorial method has been used to plan the experiments and subsequent analysis of the data using ANOVA. A total of 27 experimental runs with three process parameters were considered for experimentation. To evaluate the machining performance kerf width was calculated for each experimental run. Apart from the three input parameters, other parameters were kept constant in order to reduce their effect on actual machining.

Table 2 Machining parameters and their respective levels

Parameters	**Levels**		
	-1	**0**	**-1**
Pulse-on-time	100	105	110
Pulse-off-time	30	35	40
Peak current	210	220	230

Machining parameters are selected with the help of pilot experiments. Range and levels of machining parameters are shown in Table No. 2.

4.1 Measurement Procedure

kerf width was measured by using profile projector at magnification of 100X as shown in figure 2. The kerf width was measured at five different points and the average is recorded herein.

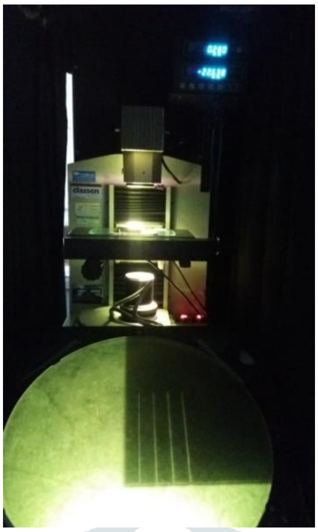

Figure 3 Schematic representation of profile projector

4.2 Experimental Design

Full factorial methodology is used to design experimentation. Full factorial experimentation method used two or more factors each with discrete possible values or "levels" and whose experimental units take on all possible combinations of these levels across all such factors. It may also be called a fully crossed design. Such an experiment allows the investigator to study the effect of each factor on the response variables, as well as the effects of interactions between factors on the response variable.

V. RESULTS AND DISCUSSION

The results of performance measures kerf width for 27 experimental trials of Wire-EDM given in Table 3. Full factorial method is adopted to study the effect of different machining variables viz. Ton, Toff and IP on Kerf width.

Table 3 3×3 factorial experiment

Run Order	Ton µs	Toff µa	IP A	Kerf µm
1	105	30	220	0.29
2	105	40	220	0.289
3	105	40	230	0.29
4	100	30	230	0.27
5	100	40	230	0.278
6	110	35	230	0.3
7	100	40	220	0.271
8	110	30	220	0.31
9	100	30	210	0.278
10	110	35	210	0.332
11	105	35	230	0.298
12	105	35	220	0.3
13	100	35	210	0.279
14	100	30	220	0.277
15	105	30	210	0.293
16	110	40	210	0.2999
17	100	40	210	0.28
18	110	30	230	0.31
19	110	35	220	0.312
20	105	40	210	0.285
21	105	30	230	0.281
22	110	30	210	0.322
23	100	35	230	0.28
24	110	40	220	0.321
25	100	35	220	0.277
26	105	35	210	0.295
27	110	40	230	0.314

5.1 Effect of different parameters on kerf width

ANOVA was performed to study the significance of the process parameters toward kerf width. The results of ANOVA are presented in Table 4. The data reveals that pulse on time is the major influencing factor, followed by pulse on time. F-ratio establishes whether the process parameter is significant or not at a particular confidence level. Higher value of F-ratio shows that any small variance of the process parameter can make a significant influence on the performance characteristics [10]. According to ANOVA for kerf width significant parameter is pulse on time having percentage contribution of 60.52%.

Table 4 Analysis of variance for kerf width

Source	Degree of Freedom	Adj SS	Adj MS	F-Value	P-Value
Ton	2	0.006171	0.003085	60.52	0.000
Toff	2	0.000141	0.000071	1.38	0.274
IP	2	0.000104	0.000052	1.02	0.379
Error	20	0.001020	0.000051		
Total	26	0.007435			

5.1.1 Regression equation for kerf width

Regression coefficients of the second order equation are obtained by using experimental data. The regression equation for the kerf width as function of three input parameters was developed and is given bellow.

$$\begin{aligned}\text{Kerf} = {} & 0.29377 - 0.01711\ \text{Ton\_100} - 0.00255\ \text{Ton\_105} + 0.01966\ \text{Ton\_110} - 0.00144\ \text{Toff\_30} \\ & + 0.00323\ \text{Toff\_35} - 0.00179\ \text{Toff\_40} + 0.00221\ \text{IP\_210} + 0.00034\ \text{IP\_220} \\ & - 0.00255\ \text{IP\_230}\end{aligned}$$

5.2 Residual plots for kerf width

Figure 4 indicates that the residuals are normally distributed for kerf width. Residuals follows an approximately straight line in normal probability plot. Plots or residuals versus fit are illustrate that residuals have constant variance. Residuals posses constant variance as they are scattered randomly around zero in residuals vs the fitted values. Since residuals exhibit no clear pattern, there is no error due to time and data collection order.

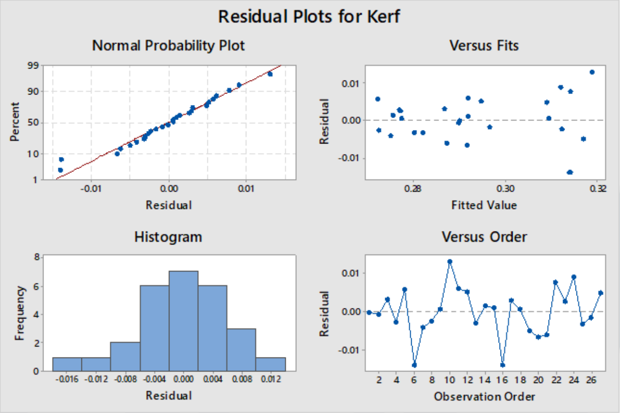

Figure 4 Residual plots for kerf width

VI. CONCLUSION

In this research, the analysis of three process parameters on kerf width as response variable is carried out using full factorial design of experiment followed by comprehensive statistical analyses (ANOVA) to identify the key factors affecting stated response variable. Moreover regression equation is developed to establish the relationship between control factors and performance measures for kerf width.

On the basis of the experimental results and their analysis, it is concluded that the main significant factors that affect kerf width is pulse on time.

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