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Review of Various Performance Parameters of Wire Electrical Discharge Machining using Taguchi Analysis

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ABSTRACT

The main goals of wire electrical discharge machine manufacturers and users are to achieve a better stability and high productivity of the process with desired accuracy and minimum surface damage and experimentally study the response of various input parameters like pulse on time, pulse off time, wire feed, wire tension and peak current on the performance parameters like material removal rate, surface flatness and wire wear ratio. Various experiments are performed under different working conditions by changing the values of pulse on time, pulse off time, wire feed and wire tension, peak current. The study concludes that the wire electrical discharge machining process parameters can be adjusted to achieve better metal removal rate, wire wear ratio and good surface flatness.

Keywords: WEDM, MRR, WRR, SF, Taguchi, Zinc coated wire.

1. INTRODUCTION

It was introduced in the late 1960s', and has revolutionized the tool and die, mold, and metal working industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages to offer. Wire electrical discharge machining (WEDM) technology has grown tremendously .In 1974, D.H. Dulebohn applied the optical line follower system to automatically control the shape of the components to be machined by the WEDM process. By 1975, its popularity rapidly increased, as the process and its capabilities were better understood by the industry. It was only towards the end of the 1970s, when computer numerical control (CNC) system was initiated into WEDM, which brought about a major evolution of the machining process. Wire electrical discharge machining is a thermal energy method of Non-Traditional Machining Methods (NTMM). In WEDM material is eroded from the job by a series of discrete sparks occurring between the electrode wire and job, separated by a dielectric fluid, which is continuously fed at the point of liberation of high amount of thermal energy.

Now a day's WEDM is a NTMM for machining of all types electrically conductive materials used in industry such as metals, metallic alloys or even some ceramic materials of any hardness . A wire which is in vertical position is fed in to the work material continuously from a supply spool to a take up spool [6]. A computer controlled positioning system is also used to maintain the gap between the tool and the work material which varies from 0.025 to 0.050 mm. the diameter of wire electrode ranges from 0.05 to 0.25 mm and its value depends upon the controlled process parameter [7,8]. This process is widely used for burr free intricate shapes which is too difficult with other conventional machining methods. It has capability of generating profile with high degree of dimensional accuracy without making any mechanical contact between tool (wire electrode) and work piece. Good surface finish with low thermal affected zone depth are obtained which minimize manual finishing operation time and fewer finishing operations are required for further finishing only in that cases in which surface finish is the primary importance. In this machining, job is not submerged in dielectric fluid as in case of electric discharge machining (EDM).

Wire cut EDM has been widely adopted as a machining tool for die materials which require high strength and hardness as well as good wear resistance, while the traditional manufacturing process needs a special tool or technique with a longer process time. In WEDM, a continuously moving conductive wire acts as an electrode and material is eroded from the work piece by series of discrete sparks between the work piece and wire electrode separated by a thin film of dielectric fluid. The dielectric is continuously fed to the spark zone to flush away the eroded material and it acts as a coolant. The schematic representation of the WEDM is as shown in Figure-1.

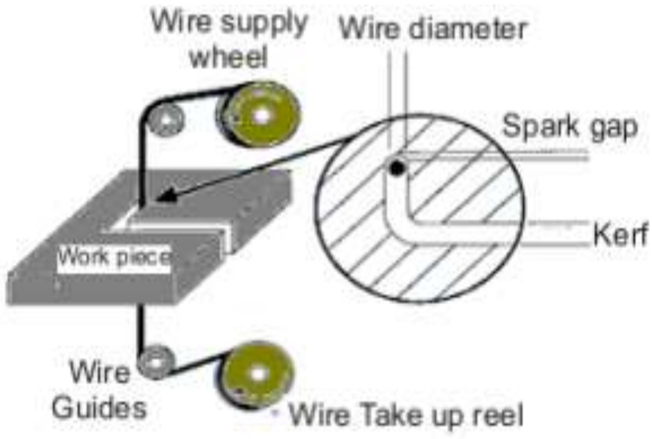

Fig. 1: Schematic Representation of WEDM

Rajurkar K.P, et al, used a factorial design method, to determine the optimal combination of control parameters in WEDM considering the measures of machining performance as metal removal rate and the surface finish. The study concluded that control factors are discharge current, the pulse duration and the pulse frequency. Y. S. Tarng, et al, used a neural network model to estimate to the effects of parameters on the surface roughness as the response variable and machining speed. J. Prohaszka in their paper they have discussed about effect of electrode material on machinability in wire electro-discharge machining that will lead to the improvement of WEDM performance. Experiments have been conducted regarding the choice of suitable wire electrode materials and the influence of the properties of these materials on the machinability in WEDM, the experimental results are presented and discussed. Y.S Liao et al. Derived an approach to determine machining parameter settings for WEDM process. Based on the Taguchi quality design and the analysis of variance (ANOVA), the significant factors affecting the machining performance such as MRR, gap width ,surface roughness, sparking frequency ,average gap voltage, normal ratio(ratio of normal sparks to total sparks) are determined. By means of regression analysis, mathematical models relating the machining performance and various machining parameters are established. Jose Maranon et.al has investigated a new method of optimizing MRR using EDM with copper-tungsten electrodes. This paper describes an investigation into the optimization of the process which uses the effect of carbon which has migrated from the dielectric to tungsten copper electrodes.

2. LITERATURE REVIEW

Literature review provides the scope for the present study. It works as guide to run this analysis. This section plays a part to get the information about wire cut electrical discharge machine and will give idea to operate the test and Form the early stage of the projects; various literature studies have been done. Research journals, books, printed or online conference article were the main sources of guidance and used as a supporting material in the project. This section includes almost the whole operation including the test, history, machining properties and results. Literature review section works as reference, to give information and guidance based on journal and other source in the media.

Datta and Mahapatra have proposed a quadratic mathematical model and conducted experiments by taking six WEDM process parameters are discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate. Experiments were carried out on D2 Tool Steel using a Zinc coated Copper wire electrode. The response parameters noticed for each experiment were MRR, Surface Roughness and Kerf. A statistical analysis has been carried for each result and responses have been utilized to fit the quadratic model which represents the above said six parameters. Grey based Taguchi technique has been utilized to evaluate optimal parameter combination to achieve maximum MRR, minimum roughness value and minimum width of cut; with selected experimental domain. It has been found out that for continuous quality improvement Grey based Taguchi method is a very reliable method to predict optimal parameter values and all the parameters involved in the experimentation are independent of each other.

Neeraj Sharma et. al. have discuss and investigate the significant process parameters along with the percentage contribution of each parameter. ANOVA is used to find the percentage contribution of significant process parameters. Response surface methodology is used for the planning of experiments and D-2 tool steel is used as a work-piece. D- 2 tool steel used in tools, punches and die industries. The k analysis of results indicates that pulse on servo voltage have the maximum effect in single parameter compared to pulse off time and peak current during the investigation of cutting rate on WEDM for D-2 tool steel.

Dr. Josephkunju Paul et.al. evalutes the effect of voltage, dielectric pressure, pulse ontime and pulse off-time on spark gap of Ti6AL4V alloy. It is found that the pulse on time, pulse off time, the interaction of dielectric pressure and pulse off time, and interaction of pulse on time and pulse off time are significant parameters which affect the spark gap of WEDM. Minimum spark gap can be obtained by adopting a low value of pulse on time (20 µs) , a high value of dielectric pressure (15 kef/cm2), high value of pulse off time(50 µs) and voltage of 50V . Improper setting of pulse on time and pulse off time can lead to wire breakage which in turn leads to increase in machining time. The developed model agrees with the conformation results by less than 6%.

Chiang et al. have been investigated on "Optimization of the WEDM process of particle reinforced material with multiple performance characteristics using grey relational analysis" employed grey relational analysis to optimize the input parameters are pulse on time, pulse off time, arc on time, arc off time, servo voltage, wire feed and water flow are optimized parameters for Al_2O_3 particle reinforced material with two response parameters are material removal rate and surface roughness. It have concluded the response table and response graph for each level of the machining parameters are obtained from the grey relational grade, and select the optimal levels of machining parameters. WEDM process are greatly improved variable factors are effectively recognized to decreasing try-error time and consuming cost in the state of increasing quality and reduce production. [10]

Hewidy et al. have been investigated correlated the inter-relationship among various input parameters namely peak current, duty factor, wire tension and water pressure with output measures namely material removal rate, wear ratio and surface roughness in wire electrical discharge machining of Inconel 601. This works established based on Response Surface Methodology (RSM). It has concluded the volumetric metal removal rate generally increases with the increase of the peak current and water pressure, Wear ratio increases with the increase of the peak current, Surface roughness increases with the increase of peak current and decreases with the increase of duty factor and wire tension.

N. Tosun et.al. employed Taguchi's approach to investigate and optimize the effects of dielectric flushing pressure, pulse duration, wire speed and open circuit voltage on kerf and MRR for AISI 4140 steel and inferred that the highly significant factors for both, the MRR and the kerf, are open voltage and pulse duration whereas dielectric flushing pressure and wire speed are less effective factors. It has also concluded that confirmation tests indicated that it is possible to decrease kerf and increase MRR significantly by using the proposed statistical technique.

3. DESIGN OF STUDY

WEDM is a stochastic process and a large number of control factors influence the process in a complex way. Any alteration even in a single parameter may produce undesirable results leading to loss of productivity, deterioration in surface quality or both apart from the unpredictable results on the material properties such as change in micro hardness and microstructure. The solution of this lies in the process analysis to generate optimal machining parameters which may involve detailed experimentation and subsequent analysis of results. In experimental studies, input variables called as control factors are changed and their effects on output performance measures (responses) are observed. Each control factor can take several values during the course of experimentation. Such values of control factors are called levels or treatments. An experiment (also called trial or run) is a combination of parameters at different levels whose effect on the output is of primary concern. For conduct of experiments, a scientific approach is necessary to plan the experiments, so as to assign equal importance to all control factors in addition to preserving robustness of the process. A properly planned and executed set of experiments is of prime importance for deriving clear and accurate conclusions from the experimental observations. The one factor at a time (OFTA) approach is a method used to plan the experiments by varying one factor at a time keeping all other factors at fixed levels. This method is effective only when emphasis is only to estimate main effects of the factors on responses, provided the experimental error is not too large as compared to factor effects such as screening experiments where it is desirable to isolate insignificant factors [Montgomery, 2002]. This method suffers from serious drawbacks that are given below:

1. OFTA approach require more number of runs to estimate effect of factors for the same precision as obtained in statistically designed experiments.
2. OFTA fails to address interactions existing between the parameters assuming that each factor behaves independently.
3. OFTA takes into account the effect of only one parameter at a time. In actual machining process, cumulative effects of different control factors yield the output.

ANALYSIS OF VARIANCE: Analysis of variance (ANOVA) is a technique for analyzing experimental data in which one or more response (or dependent) variables are measured under various conditions identified by one or more classification variables. In ANOVA, variation in the response is separated into variation attributable to differences between the classification variables and variation attributable to random error. To accomplish this, Sum of squares due to error (SS_E), Sum of squares due to regression (SS_R) and Total Sum of squares (SS_T) are utilized. The (SS_T) is divided into following four parts as shown in Table 1 to ascertain contribution of first order terms, second order terms, lack of fit element to measure the deviations of the response from the fitted surface and estimation of the experimental error from center runs.

Table 1: Analysis of variance using multiple regressions

Variation Source	Sum of Squares (SS)	Degrees of Freedom	Mean Square (MS)
Regression	$SS_R = \sum_{i=1}^{m} \sum_{j=1}^{n_i} (\hat{y}_i - \bar{y})^2$	$p-1$	$MS_R = \frac{SS_R}{p-1}$
Residuals	$SS_{residual} = \sum_{i=1}^{m} \sum_{j=1}^{n_i} (y_{ij} - \hat{y}_i)^2$	$n-p$	$MS_{residual} = \frac{SS_{residual}}{n-p}$
Lack of fit	$SS_{LOF} = \sum_{i=1}^{m} \sum_{j=1}^{n_i} (\hat{y}_i - \bar{y}_i)^2$	$m-p$	$MS_{LOF} = \frac{SS_{LOF}}{m-p}$
Pure error	$SS_{PE} = \sum_{i=1}^{m} \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_i)^2$	$n-m$	$MS_{PE} = \frac{SS_{PE}}{n-m}$
Total	$SS_T = \sum_{i=1}^{m} \sum_{j=1}^{n_i} (y_{ij} - \bar{y})^2$	$n-1$	

Where,

n = number of observations

m = total number of levels in the design

p = number of parameters of model

y = overall mean y

i = estimated value by the model for the level i;

yij = replicates performed in each individual levels;

$y\ i$ = mean of replicates performed in the same set of experimental conditions.

Based upon results obtained from ANOVA, mathematical models consisting of significant terms of individual and interaction effects are built for responses of interest.

4. EXPERIMENTAL WORK

The experiments are planned according to Taguchi's L25 orthogonal array. The experiments are mainly carried out on ELEKTRA SPRINTCUT 734 four axis wire cut EDM machine is as shown in Figure.2. The basic parts of the WEDM machine consists of a wire Electrode, a work table, and a servo control system, a power supply and dielectric supply system. The following Fig shows the ELEKTRA SPRINTCUT 734 of wire EDM. . Therefore, the width of cut (W) remains constant. Surface Roughness (Ra) is measured by handy surf (Mitutoyo surftest SJ-201P) equipment.

Fig. 2: CNC Wire cut EDM is used for experimentation

Table 2: process parameters of ELECTRONICA SPRINT CUT 734 CNC WEDM

Control parameters	Units	Symbol
Pulse On	µs	A
Pulse Off	µs	B
Peak Current	Amperes	C
Wire tension	Kg-f	D
Servo Voltage	Volts	E
Servo Feed	mm/min	F

Table 3: Variable and fixed parameters in WEDM

Machining Parameters	Working Range	Fixed Parameters	Value
Pulse On	115-131 machine unit	Composition of material	Ti6Al4V
Pulse off	63-45 machine unit	Work piece thickness	25mm
Peak current	70-230 Ampere	Wire electrode material	Brass wire Ø0.25mm
Wire tension	0-15 kg-f	Dielectric medium	Distilled water
Servo Voltage	0-99Volts	Wire feed	8m/min
Servo feed setting	0-2100 mm/min	Wire offset	0.00mm

Volume Material removal rate (VMRR) = Volume of the material removed / cutting time mm^3 /min

CONCLUSIONS

The effects of Pulse On time, Pulse Off time, Peak Current, Wire Feed rate setting are experimentally investigated in machining of Inconel-600 using CNC Wire-cut EDM process. The level of importance of the machining parameters on the material removal rate is determined by using ANOVA and it is shown that Pulse on, Pulse Off, Pea current are most significant. An optimum parametric combination for the maximum material removal rate was obtained by using Signal-to-Noise (S/N) ratio. Improved S/N ratio and conformation test indicated that it is possible to increase material removal rate by using the proposed statistical technique. The proposed mathematical model, i.e Response surface Model for the performance characteristic such as Material removal rate (MRR) in the CNC Wire-cut EDM process is successfully proposed for the proper selection of the machining parameters.

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