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An Optimization Process Parameter of Wire EDM using Response Surface Methodology

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***Abstract*: Wire-cut electrical discharge machining (WEDM) is one of the most emerging non-conventional manufacturing processes for machining hard to machine materials and intricate shapes which are not possible with conventional machining methods. This paper reviews the effects of various WEDM process parameters such as pulse on time, pulse off time, peak current, wire speed, wire tension on different process response parameters such as material removal rate (MRR), surface roughness (Ra), to optimization using RSM. This paper also reviews various optimization methods applied by the researchers and finally outlines the recommendations and future trends in WEDM research.**

***Keywords*: Wire cut EDM, Pulse on time, Pulse off time, Surface roughness, RSM.**

1. Introduction

Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact of resistance are increasing. Nevertheless, such materials are difficult to be machined by traditional machining. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) laser beam machining etc. are they applied to machine such difficult to machine materials. WEDM process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics, automobile and aerospace materials can be machined irrespective to their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, 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. However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving 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 wires and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining.

2. Working Principle of Wedm Process

The material removal mechanism of WEDM is very similar to the conventional EDM process consulting of the erosion effect producing by the electrical discharges (sparks). In WEDM material is eroded from the work piece by the repetitive sparks occurring between the gap of work piece and the wire, which is separated by a stream of dielectric fluid, which is continuous fed to the machining zone.

A voltage is excess of breakdown voltage of gap required to initiate a discharge across the gap. When such pulse is delivered to the electrode (wire) a breakdown of the electric field occurs due to ionization of the dielectric fluid at the point where the distance between surface irregularities and tool is shortest. The leads to formation of conducting electric path and a spark occur.

A very large number of sparks occur as a result of formulation of conducting path. The main response behind such occurring is great amount of discharge per second with in minor part of second. This increases both temperature (15000 to 21000 Fahrenheit) and pressure in the spark channel. A small amount of material from both work piece as well as tool is melted and vaporized by this temperature. Amount of required material removal rate (MRR) during spark can be achieved through the desire value of cutting speed and so same for desired the surface finish.

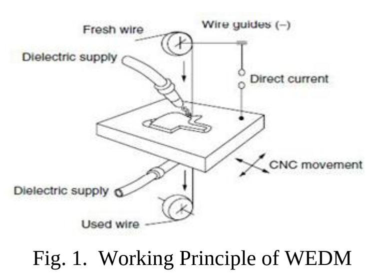

Fig. 1. Working Principle of WEDM

The chips are produce through removal material process generally carried away from work piece surface through flow of dielectric fluid with the help of nozzle attached to them. And another function of flushing system is to maintain temperature of work piece as it may change work piece properties. Absence cooling system thermal expansion with work piece so created can affected positional accuracy and work piece size.

3. Process Parameter

A. Pulse on time

The pulse on time is referred as Ton and it represents the duration of time in micro seconds, µs, for which the current is flowing in each cycle. During this time the voltage, VP is applied across the electrodes. The Ton setting time range available on the machine tool is 100-131 which is applied in steps of 1 unit. The equivalent time setting is in micro seconds.

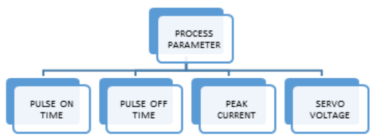

Fig. 2. Process Parameters and Performance Measures of WEDM

B. Pulse off time

The pulse off time is referred as Toff and it represents the duration of time in micro seconds, µs, between the two simultaneous sparks. The voltage is absent during this part of the cycle. The Toff setting time range available on the machine tool is 00 - 63 which is applied in steps of 1 unit. The equivalent time setting is in micro seconds.

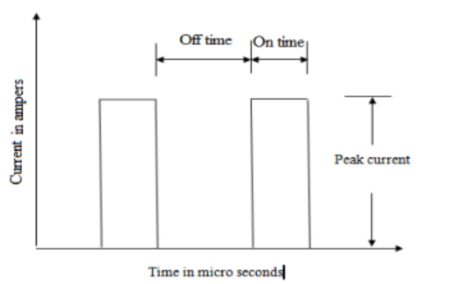

Fig. 3. Series of Electrical Pulses at the Inter Electrode Gap

C. Peak current

Peak current is the amount of power used in discharge machining and is measured in unit of amperage. The current increases until it reaches a preset value during each pulse on time, which is known as peak current, is shown in figure. Peak current is governed by surface area of cut. Higher peak current is applied during roughing operation and details with large surface area.

4. Measurement of Experimental Parameter

The discussions related to the measurement of WEDM experimental parameters e.g. surface roughness (Ra), material removal rate (MRR), are presented in the following subsections.

A. Surface roughness

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if small, the surface is smooth. Roughness is typically considered to be the high frequency; short wavelength component of a measured surface. Its represents to Ra.

5. Literature survey

Taguchi technique coupled with Grey relational analysis to optimize the input variables of WEDM on MRR, SR and GC of ballistic grade aluminium alloy has been studied. Optimization of the complex multi objective responses can be simplified through this technique. The conclusions are as follows: Results confirm that TON, IP and SV are significant variables to Grey relational grade Mathematical models were developed using response surface method for MRR, SR and IG to determine the relation between machine variables and performance measures. Optimum response characteristics such as MRR, SR and GC are improved with 6% error by employing Grey relational analysis.[1]

Analysis of silicon ingot slicing by WEDM was carried out., cutting speed and surface roughness were selected as response variables. Experiments performed show that wire diameters ranging from40 µm to120 µm can be effectively used to cut silicon wafers using the WEDM process. Accordingly, it is noted that effect to energy parameters such as current and duty cycle on silicon material is similar to the conventional material. Use of wire-EDM process for slicing of silicon ingots reduces kerf width from250 µm that is normally possible during tra-ditional abrasive saw cutting methods to 50 µm, giving a net material saving of 200–300%. The highest slicing speed of 2.5mm/min can be attained at a higher energy parameter setting. This gives an overall improvement in the slicing speed by about 40–50% over the conventional methods of silicon ingot slicing. The wire-EDM process for silicon ingot slicing improves surface roughnessto2–3 µm, Rafrom3–5 µm that is usually obtained by the conventional methods.[2]

Effects of process parameters such as pulse on time, pulse off time, servo voltage, wire speed and servo feed on performance. Characteristics, namely, MRR and surface roughness of machined components by WEDM of Ti50Ni50−xCuxSMA with brass and zinc coated brass wires have been studied. The experiments were planned as per L27orthogonal array (OA) to explore the effects of machining parameters on the proposed characteristics. The influ-ence of brass wire on the performance of WEDM (MRR, Ra, surface topography and metallographic changes) has been compared with zinc-coated brass wire. Servo voltage is the most influential factor for maximizing MRR and minimizing surface roughness. Pulse off time was also found out to be one of the influential parameters affecting MRR and surface roughness with increased pulse off time, the MRR as well as surface roughness decrease [3].

The peak current and pulse on time are the most significant parameters affecting the cutting speed, surface roughness and heat affected zone. The wire tension has minor effect on the cutting speed and heat affected zone but it has great effect on the surface roughness. ANFIS was successfully used to develop an empirical model for modelling the relation between the predictor variables (Ton, IP, and WT) and the performance parameters (CS, Ra, and HAZ). ANFIS model with gbellmf is accurate and can be used to predict cutting speed, surface roughness, and heat affected zone in wire electric discharge machining operation with average percentage errors 3.41, 3.89, and 4.1 respectively [4].

The cutting parameters taken for pulse-on time, pulse off time and wire feed rate. The measured response includes surface roughness and material removal rate. After the machining is done the surface characteristics are studied using Scanning electron microscope (SEM). Box-Benkhen approach has been used as the experimental strategy while the multi parameter optimization has been done using desirability function. The results show that pulse on time and pulse off time are the important parameters that influence the surface roughness whereas the pulse off time has major influence on material removal rate (MRR) [5].

6. Experimental Method and Analysis of Response Surface Methodology

This chapter gives the application of the response surface methodology. The scheme of carrying out experiments was selected and the experiments were conducted to investigate the effect of process parameters on the output parameters e.g. surface roughness (Ra), material removal rate (MRR) and kerf width (KW). The experimental results are discussed subsequently in the following sections. The selected process variables were varied up to three levels and box-behnken design was adopted to design the experiments.

Table 1
Level of Process Parameter

Process Parameter	Level		
	-1	0	+1
Pulse on time(μs)	80	150	220
Pulse off time(μs)	104	116	128
Peak current(Amp)	30	45	60

Various input parameter varied during the experimentation are cutting pulse on time(Ton) pulse of time (Toff) and peak current (IP). The effects of this parameter are studies on surface roughness.

A. Experimental results

The WEDM experiments were conducted, with the process parameter levels set as given in Table 2, to study the effect of process parameters over the output parameters. Experiments were conducted according to the test conditions specified by the box-behnken design. Experimental results are given in Table for surface roughness (Ra). Altogether 15 experiments were conducted using response surface methodology.

B. Analysis and result discussion

Analysis of variance of process response parameters viz. surface roughness is being carried out using MINITAB software for experimental data obtained during wire electro discharge machining of monel K-500 super alloy.

Table 2
Experimental Result

S. No.	Control parameter			Response parameter
	Ip (A)	Ton (μs)	Toff (μs)	Ra (μm)
1	80	104	45	0.82
2	200	104	45	1.35
3	80	128	45	3.04
4	200	128	45	3.35
5	80	116	30	2.13
6	200	116	30	2.19
7	80	116	60	2.51
8	200	116	60	3.04
9	140	104	30	1.12
10	140	128	30	3.31
11	140	104	60	0.99
12	140	128	60	3.71
13	140	116	45	3.16
14	140	116	45	3.15
15	140	116	45	3.15

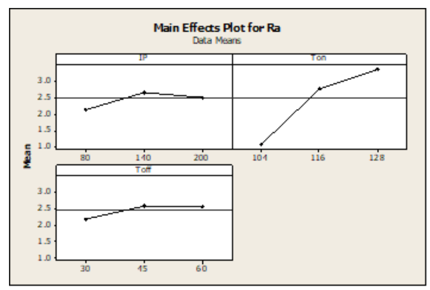

Fig. 4. Main Effect Plot for R_a

As Shown in fig, the main effects plot for R_a vs the input parameter is IP, Ton, Toff. The main effect plot indicates the performance measure R_a to different value of input parameter. Input parameter IP is increase the first R_a is increase then it's decrease. There is no major difference in R_a to increase the IP. Input parameter T_{on} is increase the R_a is increase. There is most effective T_{on} in R_a. The very high increase the value of R_a to increase the To_n. It is most effective parameter to R_a. Input parameter T_{off} is increase the first R_a increase then the decrease. T_{off} is not more effective to R_a.

7. Conclusion

Response surface methodology (RSM) was applied the independent parameters peak current, pulse on time and pulse off time in WEDM machining of monel K-500.

From the developed RSM- BBD model,

- The surface roughness (R_a) found out to achieve the minimum surface roughness as 0.82 μm the optimal process parameter combination of peak current (IP) = 80 A, pulse on time (Ton) = 104 μs and pulse off time (T_{off}) = 45 μs. Pulse on time (Ton) most significant parameter of surface roughness (R_a).

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