ISSN No.: 2455-6130
Volume 1, Issue 7, 2016, pp. 40-49

website: www.ijoetr.com

International Journal of Emerging Trends in Research

Investigation of Ni-Co Based Super During WEDM Process

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Abstract

Non conventional machining processes, wire electro discharge machining (WEDM) plays important role in precision manufacturing. In wire EDM it is very difficult to choose correct combination of machining parameters and material for various responses like surface roughness, MRR etc. Obtaining better MRR for Monel-400 by conventional machining is a difficult task. In this paper effect of WEDM parameters on surface finish Monel-400 are investigated. The Response surface methodology (RSM) was chosen for designing and conducting the experiments. The cutting rate was considered as response for improving surface quality. The Analysis of variance (ANOVA) was done to determine the optimum machining parameter combination for CR. The regression analysis method was used to formulate the mathematical model. The experimental result shows that the predicted model suggested by the RSM method is suitable for improving the CR.

Keywords: ANOVA; WEDM; CCD, Response surface, machining

1. Introduction

Non-conventional machining processes like Electro discharge machining (EDM) and wire electro discharge machining (WEDM) plays important role in precision manufacturing industries like automobile, aerospace and sheet metal industries. Especially for the manufacturing of punch, dies, jigs and fixtures. Traditional machining processes are easy to implement and execute over non conventional processes, however it is very difficult to machine complicated and complex shapes and hard materials like tool steels. Most of the times the machine tool tables provided by manufacturer do not meet the machining requirements of particular material [1]. Therefore, in many cases wire electro discharge machining plays an important role in machining complicated and intricate shapes in hard tool steels. But it needs special attention in improving the machining quality and efficiency. Hence for improving the machining efficiency and surface quality necessary attention should be given to develop some methodology and model to predict optimum combinations of machining parameters accurately. In wire EDM it is very difficult to choose correct combinations of machining parameters and materials for various responses like cutting rate

[2], [3], white layer [4] heat affected zone [5] etc. RSM has been used in number of applications to obtain the optimum parameter combinations for desired responses [5]. Pujari et. al. (2011) have tried to investigate and improve the CR of different materials namely Inconel, die steel etc. It is noted that the rigidity and higher hardness are significant properties affecting the surface roughness and wear. Therefore, high hardness and rigidity material will produce lower CR.

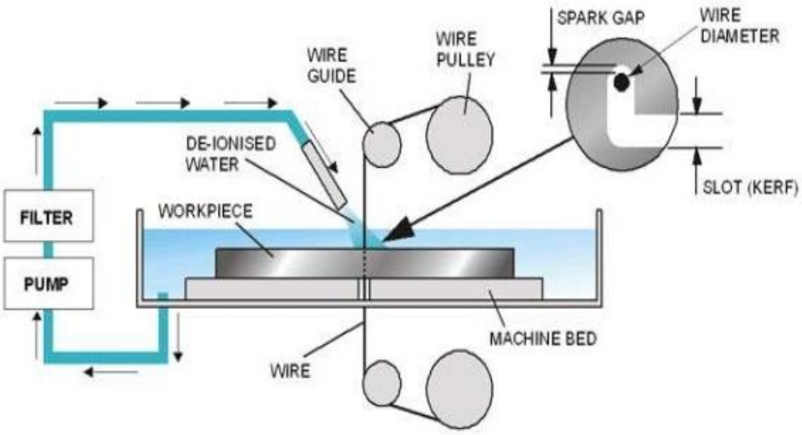

Figure 1: Schematic diagram of WEDM

2. Literature Survey

Hevidy et al. (2005) modeled the machining parameters of wire electrical discharge mining of Inconel 601 using RSM. They investigated the effect of input parameters such as peak current, duty factor, wire tension and water pressure on the metal removal rate, wear ratio and surface roughness. They concluded that the volumetric metal removal rate generally increase with increase of peak current value and water pressure This trend has been valid up to the generation of arcing, after certain limit, the increase of peak current leads to the decrease of MRR and concluded that the wear ratio increase with the increase if peak current and decrease with the increase of duty factor and wire tension. The best surface finish (Ra) that has been reached is 0.8 micron meter. Wire tension and wire speed were changed to explore their effect on machining performance, including the cutting speed, the width oil slit and surface roughness, Moreover, the wire electrode was easily broken during the machining A12O3p/606 I AI composite, so that work comprehensively investigated into the location of broken wire and the reason of wire breaking They concluded that the machining of A12O3p/6061Al composite a very low wire tension. a high flushing rate and a high wire speed were required to prevent wire breakage with an appropriate servo voltage, a short pulse-on- time and a short pulse-off-time.

Duniraj et al. (2013) described the optimization of process parameters in Wire EDM with stainless steel using single objective Taguchi method and multi objective grey relation grade. For experimentation Taguchi s LI6 orthogonal array has been used. They investigated that the effect of input parameters such as gap voltage, wire feed, pulse-on-time and pulse-off-time on the surface roughness and kerf width. By using multi-objective optimization technique grey relational theory, the optimal input parameric combination has been found as 50V gap voltage, 2mm/min wire feed, 4 μs pulse on time and 4 μs pulse off time. The analysis of variance resulted that the pulse-on-time has major influence in the surface roughness and kerf width,

Kanlayasiri and Boonmung (2007**)** investigated influence of wire-EDM machining variables on surface roughness of newly developed DC53 die steel of width, length, and thickness 27, 65 and 13 mm, respectively. The machining variables included pulse on time, pulse off time, peak current and wire tension. The variables affecting the surface roughness were identified using ANOVA technique. Result showed that the pulse on time and peak current were significant variables to the surface roughness of wire-EDM DC53 die steel. The maximum prediction error of the model was less than 7% and average percentage error of prediction was less than 3%. Kanlayasiri and Boonmung (2007) investigated the effects of wire EDM machining parameters on surface roughness of DC53 die steel. The investigated machining parameters were pulse-on time. pulse-off time, pulse-peak current and wire tension Analysis of variance (ANOVA) technique was used to find out the parameters affecting the surface roughness. Assumptions of ANOVA were examined through residual analysis. Quantitative testing methods on residual analysis were employed in place of the typical qualitative testing techniques. Results from ANOVA showed that pulse-on time and pulse peak current are significant variables for surface roughness. The surface roughness of test specimen increased as these two variables increased

Mgoudar and Sadashivappa (2013) investigated the effect of machining parameters on no and surface roughness in machining of ZA43/SiCp composite by WEDM. They investigated that the effect of input parameters likes current, pulse-on-time, pulse-off-time on be MMR and surface roughness. They observed a reduction in the MMR and increase in surface roughness for increased reinforcement in the composite They also observed that increment in applied current and pulse-on-time increases the MMR Pudand Bhattacharyya (2005) an attempt has been made to model the white layer dept through response surface methodology (RSM) in WEDM process comprising a rod cut followed by a trim cut. An experimental plan of rotatable central composite desk considering of four input variables, such as the pulse off-time during rough cutting (RT on) and pulse-on-time (TT on), offset and cutting speed during cutting have been modesty. It was concluded that the white layer depth increased with increased pulse-on- structuring the first rough cut and subsequently decreased while increasing pulse-on- time during trim cutting. The white layer depth reduce with decreasing wire tool off-set during trim cutting

Satishkumar et al. (2011) reported the investigation of the machining characteristics of AI6063/SiCp composites material in WEDM. in this investigation, the effect of wire electrical discharge machining (WEDM) parameters such as pulse-on time (Ton), pulse-off time (Toff), gap voltage (V) and wire feed (F) on material removal rate (MRR) and surface roughness (Ra) was studied. The AI6063 is reinforced with SiCp in the from of particles with 5%, 10% and 15% volume fractions. The experiments are carried out as per design of experiments approach using L9 orthogonal array. The results were analyzed using analysis of variance and response graphs. The results were also compared with the results obtained for unreinforced A16063. Generally, it was found that the increase in volume percentage of SiC resulted in decreased MRR and increased Roughness. Regression equations have been developed based on the experimental data for the prediction of output parameters for AI6063 and composites.

3. Experimental procedure

In present work, a 5 axis sprint cut WEDM is used for conducting the experiments, made by Electronica M/C Tool LTD, india. The performance of WEDM depends on setting of process parameters. Following section discusses the work material, machining parameters and experimental design used for present study.

MONEL nickel alloy is a solid solution alloy that can be hardened by the process of cold working. MONEL is a trademark of Special Metals Corporation under which a series of nickel-copper alloys are grouped. Commercially there are many types of MONEL available, such as alloy 400, alloy 401, alloy R-405, Alloy K-500 and Monel 404. The Monel 400 alloy is also known as super alloy monel. This alloy is available in some standard shapes such as hexagon, round, tube, pipe, plate, strip, sheet and wire. The proportions of copper and nickel used to make monel are the same as that found in the nickel ore found in mines. This alloy exhibits good corrosion resistance. This datasheet will look into the chemical composition, properties and applications of MONEL 400 alloy.

Table 1: The composition of Monel 400 is as follows:

Element	**Content (%)**
Nickel, Ni	Remainder
Copper, Cu	28-34
Iron, Fe	2.5 max
Manganese, Mn	2 max
Silicon, Si	0.5 max
Carbon, C	0.3 max
Sulphur, S	0.024

Four discharge parameters, viz. Ip, Ton, Toff and SV are selected as input variable parameters other remaining least significant parameters are kept constant. A brass wire (zinc coated) of diameter 0.25 mm is selected as wire electrode. Wire feed rate 5 m/min is used with wire tension 10N. All experiments are performed at zero wire offset value. The distilled water having conductivity, 20mho is used as a dielectric fluid with high flow rate (i.e. 12 L/min). Selected levels and range of four variable input parameters are shown in Table 1 series of experimental trials have been conducted as per response surface methodology (RSM). The details about the work material, experimental set-up and measuring apparatus, selection of process parameters and their range, design of experiments, and reproducibility have been explained in the following sections.

3.2 Selection of process parameters and their range

In the present work, the effect of various process parameters (factors) such as viz., , Ton, Toff and SVon CR (response parameters) has been investigated. These process parameters and their range have been selected on the basis of the existing literature, pilot experimentation, manufacturer’s manual, and machine capability. The independent process parameters and their levels in coded and actual values are shown in Table 2.

Box and Hunter [4] proposed that the scheme based on central composite design (CCD) fits the second-order re- sponse surfaces quite accurately. Also, CCD [12] is the most popular among the various classes of RSM designs due to its flexibility, ability to run sequentially, and efficiency in providing the overall experimental error in a minimum number of runs. Therefore, it has been selected in the present work. In CCD, each factor is varied at five levels (−α, −1, 0, 1, α) for developing a second-order. When the number of factors (k) is five or greater, it is not necessary to run all combinations of factors. The factorial part of the design can be run using a fraction of the total number of available combinations. The possible designs options can either be regular fractional factorials.

4. Results and discussion

The present 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 parameter e.g. CR. The experimental results are discussed subsequently in the following sections. The selected process variables were varied up to four levels and central composite rotatable design was adopted to design the experiments. Response Surface Methodology was used to develop second order regression equation relating response characteristics and process variables.

4.1 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 second order central composite design (Table 3). Experimental results are given in Table 3 for CR. Altogether 21 experiments were conducted using response surface methodology.

Table 2: Process parameters and their levels

Coded Factors	**Real Factors**	**Parameters**	**Levels**		
			(-1)	**(0)**	**(+1)**
A	Ton	Pulse on Time	110	120	130
B	Toff	Pulse off Time	115	127	140
C	SV	Spark Gap Set Voltage	30	37	45
D	IP	Peak Current	30	40	50

4.2 Analysis and discussion of results

The experiments were designed and conducted by employing response surface methodology (RSM). The selection of appropriate model and the development of response surface models have been carried out by using statistical software, “Design Expert (DX-9)”.

The regression equations for the selected model were obtained for the response characteristics viz. CR. These regression equations were developed using the experimental data (Table 3.) and were plotted to investigate the effect of process variables on various response characteristics. The analysis of variance (ANOVA) was performed to statistically analyze the results.

Table 3: Observed Values for Performance Characteristics

		Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Response 1**
Std	Run	A:Peak current	B:Pulse on time	C:Pulse off time	D:Servo voltage	Cutting Speed
1	5	130	140	45	30	2.704
2	17	130	140	30	30	2.892
3	14	130	115	45	50	0.916
4	18	110	140	30	50	2.356
5	9	130	115	30	50	1.4
6	2	110	115	45	30	1.052
7	10	110	140	45	50	2.168
8	13	110	115	30	30	1.464
9	16	110	127	37	40	2.185
10	11	130	127	37	40	2.385
11	1	120	115	37	40	1.45
12	21	120	140	37	40	2.71
13	19	120	127	30	40	2.445
14	8	120	127	45	40	2.145
15	6	120	127	37	30	2.53
16	4	120	127	37	50	2.23
17	12	120	127	37	40	2.38
18	3	120	127	37	40	2.38
19	7	120	127	37	40	2.38
20	20	120	127	37	40	2.38
21	15	120	127	37	40	2.6

4.3.1 Selection of Adequate Model

To decide about the adequacy of the model, three different tests viz. sequential model sum of squares, lack of fit tests and model summary statistics were performed for cutting rate, characteristics of WEDM process. The sequential model sum of squares test in each table shows how the terms of increasing complexity contribute to the model. It can be observed that for all the responses, the quadratic model is appropriate. The „lack of fit‟ test compares the residual error to the pure error from the replicated design points. The results indicate that the quadratic model in all the characteristics does not show significant lack of fit, hence the adequacy of quadratic model is confirmed. Another test „model summary statistics‟ given in the following sections further confirms that the quadratic model is the best to fit as it exhibits low standard deviation, high "R-Squared" values, and a low "PRESS"

4.3.2 Effect of Process Variables on Cutting Rate

The regression coefficients of the second order equation is obtained by using the experimental data (Table 3). The regression equation for the cutting rate as a function of five input process variables was developed using experimental data and is given below. The coefficients (insignificant identified from ANOVA) of some terms of the quadratic equation have been omitted.

$$\begin{aligned} \mathit{CuttingSpeed} = {} & 59.30671 + 0.47442 * \mathit{Peakcurrent} + 0.49211 * \mathit{Pulseontime} \\ & * \mathit{Cutting\ Speed}\ - 53.31495 + 0.28680\ * \mathit{Peak\ current} + 0.5486 \\ & *\ \mathit{Pulse\ on\ time}\ + 0.030683 * \mathit{Pulse\ off\ time} - 0.015720 * \mathit{Servo\ voltage} \\ & + 6.93333E - 004 *\ \mathit{Pulse\ on\ time}\ *\ \mathit{Pulse\ off\ time} - 1.15033E - 003 \\ & *\ \mathit{Peak\ current}2 - 2.04821E - 003\ *\ \mathit{Pulse\ on\ time}2 - 1.86724E - 003 \\ & *\ \mathit{Pulse\ off\ time}2 + 0.18246 * \mathit{Pulseofftime} - 0.020960 * \mathit{Servovoltage} \\ & + 1.04000E - 003 * \mathit{Pulseontime} * \mathit{Pulseofftime} - 2.04502E - 003 \\ & * \mathit{Peakcurrent}^2 - 2.04821E - 003\ * \mathit{Pulseontime}^2 - 4.20130E - 003 \\ & * \mathit{Pulseofftime}^2 \end{aligned}$$

The above response surface is plotted to study the effect of process variables on the cutting rate and is shown in Figures 4.1a-4.1b. From Figure 4.1a the cutting rate is found to have an increasing trend with the increase of pulse on time and decrease the peak current peak current. This establishes the fact that cutting rate is proportional to the energy consumed during machining and is dependent not only on the energy contained in a pulse determining the crater size, but also on the applied energy rate or power. It is observed from Figure 4.1b that cutting rate decreases with increase servo voltage. With increase in spark voltage the average discharge gap gets widened resulting into a lower cutting rate. It is seen from Figure 4.1b that cutting rate increases with increase in the peak current values. The higher is the peak current setting, the larger is the discharge energy. This leads to increase in cutting rate. But, the sensitivity of the peak current setting on the cutting performance is stronger than that of the pulse on time. While the peak current setting is too high, wire breakage may occur frequently. It is seen from Figure 4.1d that cutting rate almost remains constant with increase in the peak current. Though with increase in peak current, the machining stability increases as vibrations get restricted. But its increment does not influence the cutting rate much.

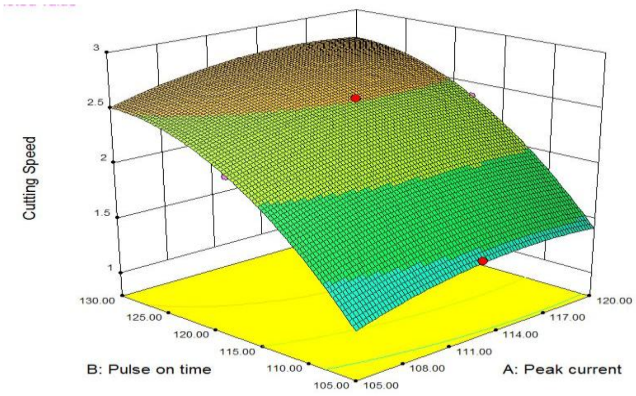

Figure 2: Combined Effect Of Pulse on Time And Peak Current On Cutting Rate

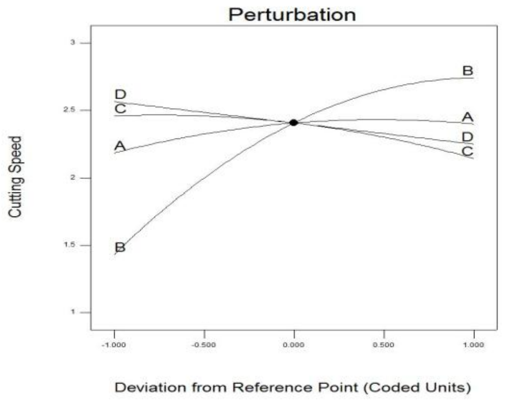

Figure 3: Overall performance of Cutting Rate

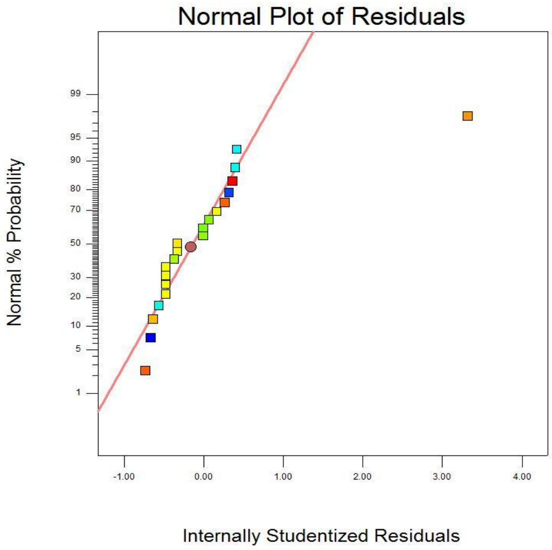

Figure 4: Normal Plot of Residuals for Cutting Rate

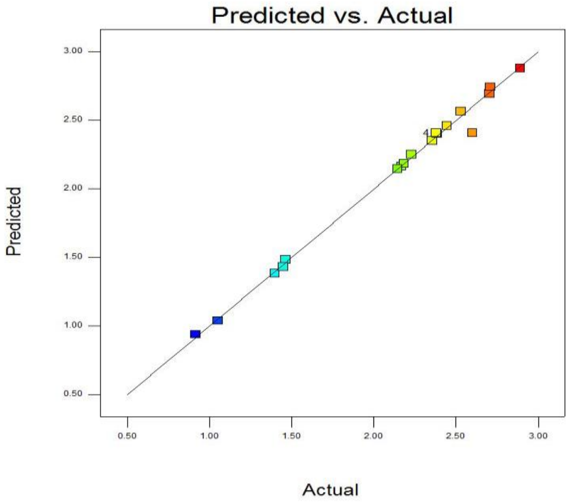

Figure 5: Predicted and actual value for Cutting Rate

The residual analysis as a primary diagnostic tool is also done. Normal probability plot of residuals has been drawn (Figure 4.2). All the data points are following the straight line. Thus the data is normally distributed. It can be seen from Figure 4.3 that all the actual values are following the predicted values and thus declaring model assumptions are correct.

5. Conclusions

In the previous chapter, the effect of machining parameters of WEDM on the response variables such as CR the material (Monel-400) has been discussed. Also the optimal levels of the machining parameters for each of response variables have been found out using response surface methodology (RSM), the important conclusions drawn from the present study are summarized below:

1. The sensitivity of the current setting on the cutting performance is stronger than that of pulse on time. Pulse off time (p value 0.0002) is the most significant factor for surface CR
2. The experimental values are in good agreement with the predicted values, thus the optimized results are validated.

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