Process Parameter Optimization for WEDM using Taguchi Method and Advanced Optimization Algorithms

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ABSTRACT

Abstract- With the increasing demands of high surface finish and machining process aer now being replaced by non-traditional processes. Wire electro discharged machining is one of the non-traditional machining processes. Surface roughness and material removal rate of crucial important in the field of machining processes. This study uses Taguchi optimization technique, in order to optimize the cutting parameters in wire Electro Discharge Machining. The objective of optimization is to attain the best surface quality and max material removal rate simultaneously and separately. For each experiment surface roughness and material removal rate is determined by using multi objective optimization technique gray relation theory, the optimal value is obtained for surface roughness and Material Removal Rate and by using Taguchi optimization technique, optimized value is obtained separately. The study employs Piratical Swarm Optimization, Genetic algorithm,Simulated Anneling to optimize the machining parameters that lead to a maximum material removal rate, minimum surface roughness values for Wire Electrical Discharge Machining. The machining parameters are evaluated by Taguchi's Orthogonal Array. Experiments are conducted on a Computer Numerical Control and output responses such as material removal rate, surface roughness are measured.

Key Word: Wire Electro Discharge Machining , Taguchi, Minitab, Optimization, ANOVA.

INTRODUCTION

Wire electrical discharge machining process is a non-traditional machining alternative in which material is removed by generating a series of discrete sparks between electrode and work piece immersed in a liquid dielectric medium. WEDM is widely used in various fields like mould-making tool and die industries, medical, aerospace applications, automotive and electronics industries to make intricate shapes and profiles in extremely hard materials like titanium, zirconium, molybdenum, and tool and die steel etc. WEDM is a highly non-linear and complex machining process controlled by a large number of process parameters such as pulse-on time, pulse-off time, pulse current, gap voltage, wire speed, wire feed, wiretension.Any slight deviation in the process parameters can affect the performance characteristics which include material removal rate, dimensional accuracy, surface roughness and cutting speed, kerf width.

2. LITERATURE REVIEW

Kapil and Sanjay [15] applied Multi-objective genetic algorithm NSGA-II to optimize the multiple objectives of MRR and surface roughness on machining high speed steel(M2, SKH9). Experiments, based on Taguchi's parameter design, were carried out to study the effect of various parameters and mathematical models were developed between machining parameters and responses like metal removal rate and surface finish by using nonlinear regression analysis. These mathematical models were then optimized by using multi-objective optimization technique based on NSGA-II to obtain a Pareto-optimal solution set. The results of optimization indicate that the MRR and surface finish are influenced more by pulse peak current, pulse duration, pulseoff period and wire feed than by flushing pressure and wire tension. Results also indicate that the surface quality decreases as the MRR increases and they vary almost linearly.

Other relevant contributions on multi objective optimization have been carried out by Konda et al., [16], Susanta and Shankar [17], Prasad and Gopala Krishna [18], Susanta and Shankar [19] and Pandu et.al.,[20] Kuriakose et al., [21], experiments were carried out and applied data mining technique to model the WEDM process. A data mining technique C4.5 was used to study the effect of various input parameters on the outputs, namely the cutting speed and surface finish.

Lee and Liao[23],developed a gain Self-tuning fuzzy control system to cope with the conditions that often occur with wire rupture in WEDM process, such as an improper setting of machining parameters, machining the workpiece with varying thickness etc.

Kumar Muthu, Babu Suresh[26], et all demonstrates optimization of Wire Electrical Discharge Machining process parameters of Incoloy800 super alloy with different performance characteristics such as Material Removal Rate, surface roughness and Kerf based on the Grey relational and Taguchi Method.

Kumar Mohan and Biswas Chandan Kumar [28],used Response surface methodology to investigate the relationships between the three controllable variables on the material removal rate. Experiments are conducted on AISI D2 tool steel with copper electrode and three process variables (factors) as discharge current, pulse duration, and pulse off time.

H. Singh, R. Garg[31] took experiments for finding the effects of various process parameters of WEDM like pulse on time, pulse off time, gap voltage, peak current, wire feed tension have been investigated to reveal their impact on material removal rate of hot die steel(H-11), using one variable at a time approach.

At present, WEDM is a widespread technique used in industry for high-precision machining of all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials, of any hardness (Ho K H, Newman *et al.*, 2004; Gatto A and Luliano L, 1997; Puertas I andLuis C J, 2003).

.**PragyaShandilya , P. K. Jain, N. K. Jain(2012) [29**] , present study to optimize the process parameters during machining of SiCp/6061 Al metal matrix composite by wire electrical discharge machining using response surface methodology.

Neeraj et al[25],conducted experiments to investigate the effect of process parameters on cutting speed and dimensional deviations in cutting high-strength low-alloy steel. To optimize the process parameters for cutting speed and dimensional deviation, Response Surface Methodology was used. From the experimental results it is found that pulse-on time was the most prominent factor for cutting speed and dimensional deviation. In order to improve the performance measures namely surface roughness, cutting speed, dimensional accuracy and material removal rate of the WEDM process several researches were attempted previously shaft so that propeller revolut speed was regarded to equal to engine revolution speed.

PROCESS PARAMETERS

- **Pulse on time**

Pulse on time, is expressed in micro seconds. During the pulse on time, the voltage is applied in the gap between workpiece and the electrode thereby producing discharge. Higher the pulse on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate depends upon the amount of energy applied during the pulse on time.

- **Pulse off time**

Pulse interval, also referred as Pulse off time, is also expressed in micro seconds. This is the time between discharges. Off Time has no effect on discharge energy. Off Time is the pause between discharges that allows the debris to solidify and be flushed away by the dielectric prior to the next discharge. Reducing Off Time can dramatically increase cutting speed, by allowing more productive discharges per unit time. However, reducing Off Time, can overload the wire, causing wire breakage and instability of the cut by not allowing enough time toevacuate the debris before the next discharge.

- **Wire Feed rate**

As the wire feed rate increases, the consumption of wire as well as cost of machining will increase. Low wire speed will cause wire breakage in high cutting speed.

- **Wire Tension**

If the wire tension is high enough the wire stays straight otherwise wire drags behind. Within considerable range, an increase in wire tension significantly increases the cutting speed and accuracy. The higher tension decreases the wire vibration amplitude and hence decreases the cut width so that the speed is higher for the same discharge energy. However, if the applied tension exceeds the tensile strength of the wire, it leads to wire breakage.

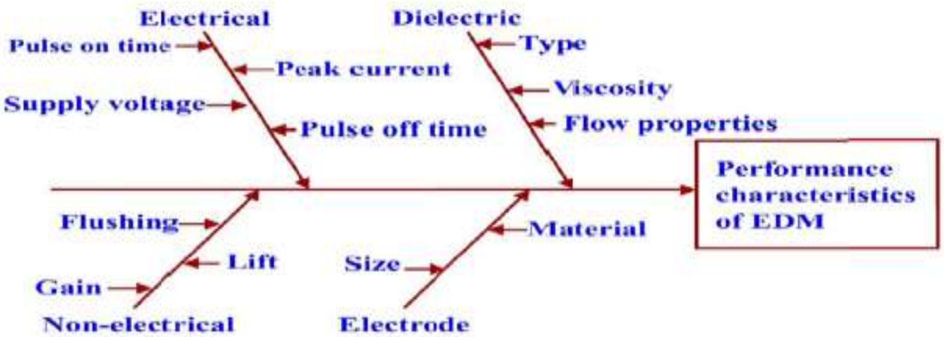

Fig.1: Ishikawa cause and effect diagram for EDM

MATERIAL AND METHOD

Work Material

Incoloy800, High strength temperature resistant (HSTR) alloy, was used for the present investigation. The table 1 shows the chemical composition of Incoloy800.

Chemical composition	C	Cr	Mn	Al	Mo	Ni	Fe	Ti	W	V	Co
Wt%	0.096	20.096	0.501	0.302	0.335	34.991	42.821	0.304	0.066	0.027	0.07

Table 1 chemical composition of Incolony 800

Methodology

The four phases used in this research are summarized as follows:

First Phase : Select the process parameters for WEDM.

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Second Phase : Assessment of real experiment data in WEDM using Taguchi's Orthogonal Array.

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Third Phase : response parameters MRR and RA are measured

EXPERIMENTAL PROCESS:

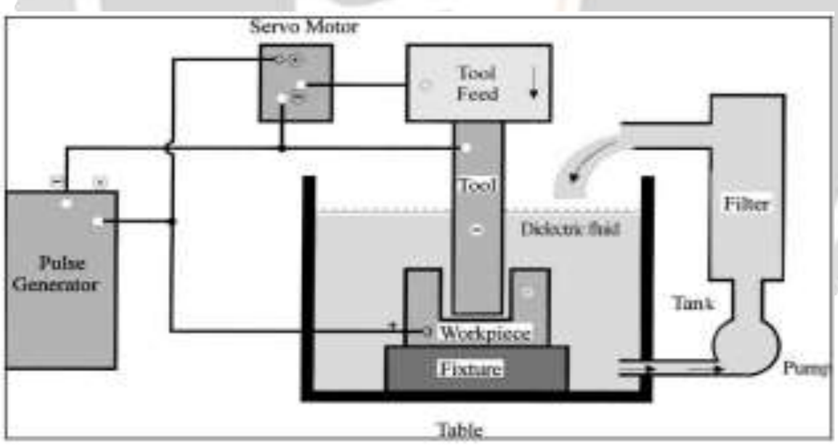


Fig: 2 Experimental set up

The experiments were performed on Robofil 100 high precision five axis CNC WEDM, which is manufactured by Charmilles Technologies Corporation. The basic parts of the WEDM machine consists of a wire, a work table, a servo control system, a power supply and dielectric supply system. The Robofil 100 allows the operator to choose input parameters according to the material and height of the work piece and tool material from a manual provided by the WEDM manufacturer. The Robofil 100 WED machine has several special features. The pulse power supply uses a transistor controlled RC circuit. The discharge energy is determined by the value of the capacitor that is parallel to the machining gap. The experimental set-up for the data acquisition of the sparking frequency and machine table speed is illustrated in the Fig. 2. The WEDM process generally consists of several stages, a rough cut phase, a rough cut with finishing stage, and a finishing stage. During the rough cut phase metal removal rate is of primary importance. Only during the rough cut with finishing stage are metal removal rate and surface finish both of primary importance. This means that the rough cut with.finishing phase is the most challenging phase because two goals must simultaneously be considered. We shall therefore consider the rough cut with finishing phase here.

DESIGN OF EXPERIMENTS:

Taguchi Method

By using Robofil 100 WEDM, the input parameters are to be chosen from a limited set of possible values. The values of input parameters which are of interest in the rough cut with finishing phase are recorded. To evaluate the effects of machining parameters on performance characteristics (MRR and SF), and to identify the performance characteristics under the optimal machining parameters, a specially designed experimental procedure is required. Classical experimental design methods are too complex and difficult to use. Additionally, large numbers of experiments have to be carried out when number of machining parameters increases. Therefore, Taguchi method, a powerful tool for parameter design, was used to determine optimal machining parameters for maximum MRR and SF in WEDM. The control factors are used to select the best conditions for stability in design of manufacturing process, whereas the noise factors denote all factors that cause variation.

Taguchi proposed to acquire the characteristic data by using orthogonal arrays, and to analyze the performance measure from the data to decide the optimal process parameters. In this work, it is planned to study the behavior of six control factors viz., A, B, C, D, E, and F and two interactions viz., A×B and A×F, based on past experience and extensive literature review.

The experimental observations are further transformed into a signal-to-noise (S/N) ratio. There are several (S/N) ratios available depending on objective of optimization of the response. The characteristic with higher value represents better machining performance, such as MRR, is called 'higher is better, HB'.Inversely, the characteristic that has lower value represents better machining performance, such as SF. Therefore, "HB" for the MRR, and "LB'' for the SF were selected for obtaining optimum machining performance characteristics. The loss function (L) for objective of HB and LB is defined as follows, where *yMRR* and *ySF* represent response for metal removal rate and surface finish respectively and 'n' denotes the number of experiments.

ORTHOGONAL ARRAY

Exp.no	1	2	3	4	5
1	1	1	1	1	1
2	1	1	1	1	2
3	1	1	1	1	3
4	1	2	2	2	1
5	1	2	2	2	2
6	1	2	2	2	3
7	1	3	3	3	1
8	1	3	3	3	2
9	1	3	3	3	3
10	2	1	2	3	1
11	2	1	2	3	2
12	2	1	2	3	3
13	2	2	3	1	1

14	**2**	**2**	**3**	**1**	**2**
15	**2**	**2**	**3**	**1**	**3**
16	**2**	**2**	**3**	**1**	**3**

Table 2 Orthogonal array

Symbol	Control factors	Level 1	Level 2	Level 3
A	Pulse-on time, , µs	115	120	125
B	Pulse – off time, µs	40	45	50
C	Wire tension	8	10	12
D	Wire feed, mm/min	1	2	3

Table 5.2

Experimental Data

The experiments were performed on Robofil 100 high precision five axis CNC WEDM, which is manufactured by Charmilles Technologies Corporation. The basic parts of the WEDM machine consists of a wire, a work table, a servo control system, a power supply and dielectric supply system. The Robofil 100 allows the operator to choose input parameters according to the material and height of the work piece and tool material from a manual provided by the WEDM manufacturer. The Robofil 100 WED machine has several special features. The pulse power supply uses a transistor controlled RC circuit. The discharge energy is determined by the value of the capacitor that is parallel to the machining gap. The experimental set-up for the data acquisition of the sparking frequency and machine table speed is illustrated in the Fig. 2. The WEDM process generally consists of several stages, a rough cut phase, a rough cut with finishing stage, and a finishing stage. During the rough cut phase metal removal rate is of primary importance. Only during the rough cut with finishing stage are metal removal rate and surface finish both of primary importance. This means that the rough cut with finishing phase is the most challenging phase because two goals must simultaneously be considered. We shall therefore consider the rough cut with finishing phase here.

- Orthogonal array experiment

To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is. For example, a three-level process parameter counts for two degrees of freedom. The degrees of freedom associated with interaction between two process parameters are given by the product of the degrees of freedom for the two process parameters.

Ex.no.	parameter level				MRR (g/min)	Ra (µm)	Kerf width (mm)
1	1	1	1	1	0.04833	3.11	0.317
2	1	2	2	2	0.05351	3.31	0.324
3	1	3	3	3	0.05128	3.6	0.299
4	2	1	2	3	0.04192	3.67	0.33
5	2	2	3	1	0.04295	3.97	0.322
6	3	1	3	2	0.05011	4.04	0.343
7	3	2	1	3	0.03844	4.11	0.356
8	3	2	1	3	0.03974	4.26	0.368

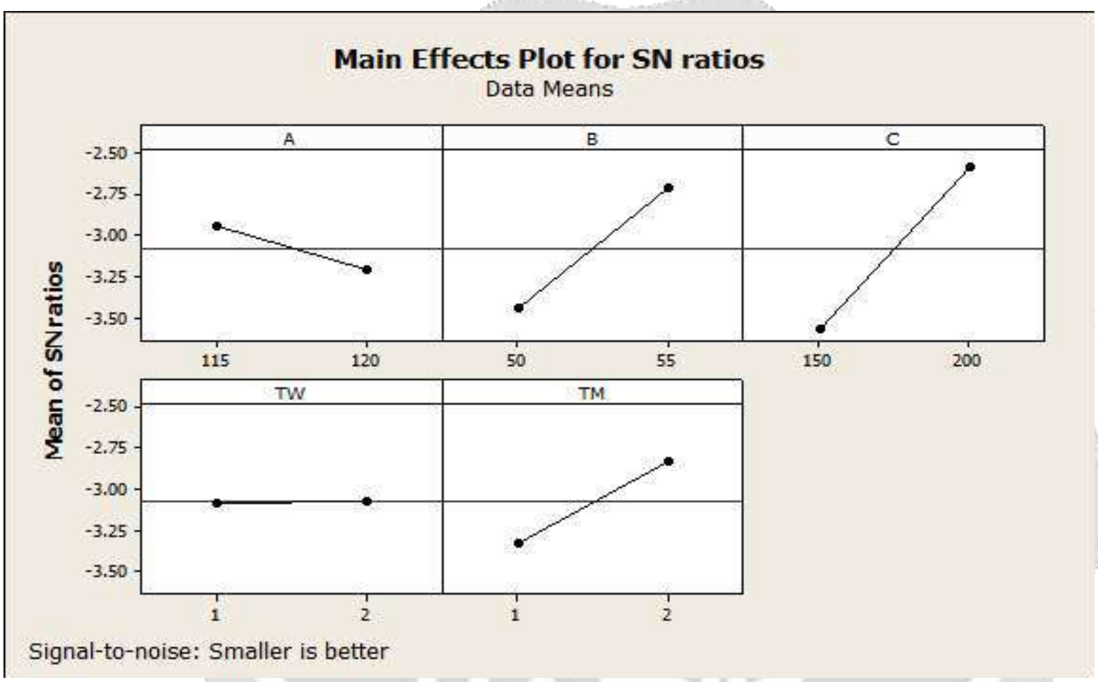
Table 6.1

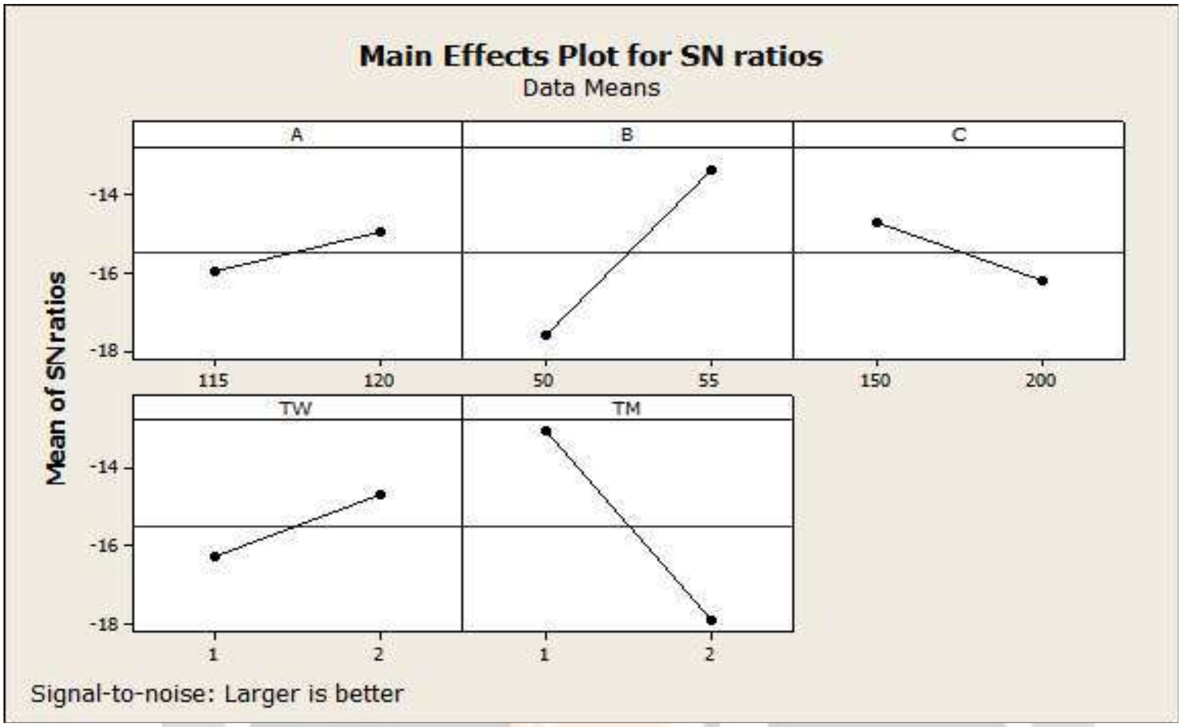
As mentioned earlier, there are three categories of performance characteristics, i.e., the lower-the-better, the higher-the-better, and the nominal-the-better. To obtain optimal machining performance, the lower-the-better performance characteristic for surface roughness should be taken for obtaining optimal machining performance.

- Analysis of variance

The purpose of the ANOVA is to investigate which of the process parameters significantly affect the performance characteristics. This is accomplished by separating the total.

RESULTS





(b) optimal set of input parameters for maximum MRR

CONCLUSIONS

This paper has presented an application of the parameter design of the Taguchi method in the optimization of operations.

- Taguchi robust orthogonal array method is sutaible to analyze the surface roughness (metal cutting) problem as described in this paper.
- It is found that the parameter design of the Taguchi method provides a simple, systematic and efficient methodology for the optimization of the cutting parameter.
- Surface roughness can be improved simultaneously through this approach instead of using engineering judgement. The confirmation experiments were conducted to verify the optimal cutting parameters.

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