

Process Parameters Optimization of Super Nickel -718 In Wire EDM by Using Taguchi Method

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ABSTRACT: Wire EDM is more efficient than unconventional machining process which is mainly used for machining of materials difficult to machine like composite and inter metallic materials. WEDM plays an important role in manufacturing industries like aerospace, automobiles and Engineering etc. Intricate profiles used in prosthetics, bio-medical applications can also be done in WEDM. Improving the machining efficiency of various shapes of structure components in the WEDM consist of number of parameters which make difficult to obtain optimal parametric combinations for various responses like surface roughness, material removal rate, and dimensional deviation. Super Ni-718 can easily be machined on WEDM with reasonable cutting speed and surface finish. It is difficult to machine Super Ni-718 on conventional machining because of its outstanding high temperature strength and extreme toughness. In the present work the process parameters like pulse on time, pulse off time, wire tension and surface roughness are considered to optimize SR, MRR and DD. Taguchi L9 orthogonal array along with ANOVA is used for optimize the different process parameters.

KEYWORDS : WEDM, Super Nickel-718, ANOVA, Taguchi method.

I. INTRODUCTION

Super Ni-718 is a nickel-based high-temperature strength super alloy found applications in aerospace, missile, nuclear power, chemical and petrochemical. Marine and space shuttle components. The characteristics such as higher strain hardening tendency, high dynamic shear strength and poor thermal diffusivity are the major causes of difficulty in machining of this alloy. These in turn, produce higher cutting forces, highly strain hardened and toughened chips. and excessive tool wear and cause surface damages extending to subsurface levels. In various process cutting tool and work material-related parameters have complex interactions during machining. All these effects in general hamper the machinability of this alloy.

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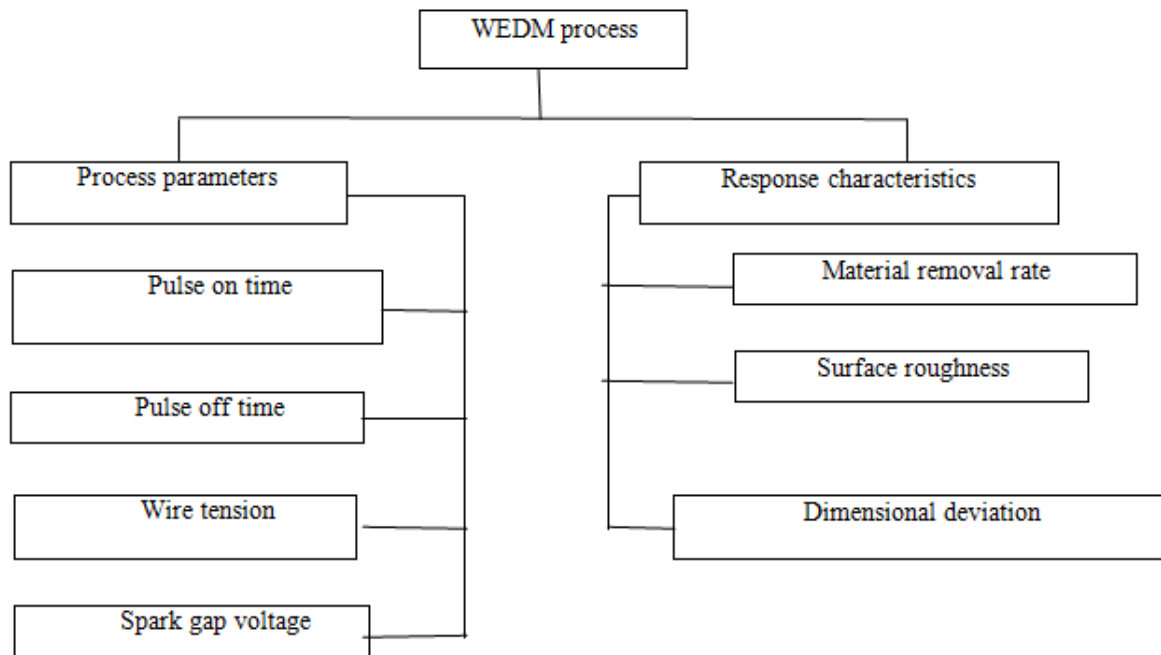


Figure: 1. Process parameters and response characteristics

II. LITERATURE REVIEW

Tarnag et al [1] used feed forward neural network to construct the WEDM process model to associate the cutting parameters and the responses include machined surface roughness and machining speed. Lee et al. [2], 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 work piece with varying thickness etc. Shandilya et.al. [3], attempted to optimize the Kerf in machining of Sic/6061 Al MMC using response surface methodology (RSM). Aminollah Mohammadi et al., [4]-Statistical analysis of wire electrical discharge turning on material removal rate was made. The review on the state performance machining of advanced materials using Die sinking EDM, WEDM, Micro- EDM, Dry EDM AND RDE-EDM is presented by Anand pandey et.al.[5]. Mustafa Ilhan Gokler et al [6] present the experimental study to select the most suitable cutting and offset parameter combination for the wire electrical discharge machining process in order to get the desired surface roughness value or the machined work pieces. The variations of cutting performance with pulse time, open circuit voltage; wire speed and dielectric fluid pressure were experimentally investigated in Wire Electrical Dis-charge Machining (WEDM) process studied by Nihat Tosur et al. [7]. Miller et al. [8] investigated the effect of spark on-time duration and spark on-time ratio on the material removal rate (MRR) and surface integrity of four types of advanced material; porous metal foams, metal bond diamond grinding wheels, sintered Nd-Fe-B magnets and carbon-carbon bipolar plates. Singh et al.[9] investigated MRR of hot die steel (H 11) by varying various process parameters such as pulse on time (T ON), pulse off time (T OFF), spark gap voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT) and also predicted values for these process parameters to maximize MRR. Signal-to-noise ratio basically reflects the variability in the response of a system caused by noise factors Khoei et. al (10). There are varieties of S/N ratio characteristics, the selection of which is problem specific. The commonly used S/N ratio characteristics in quality engineering attempted by Phadke and Roy et al (11, 12). Owing to all these problems, it is very difficult to machine Super Ni-718 by conventional machining processes and moreover, by conventionally used tool materials. After a comprehensive study the existing literature, a number of gaps have been observed in WEDM.

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In the present work was investigated that in multiple directions starting from experimental investigations to parametric optimization during wire electrical discharge machining of super Ni-718.

III. EXPERIMENTAL SETUP AND PROCEDURE

In Taguchi method, process parameters which influence the products are separated into two main groups: control factors and noise factors. The control factors are used to select the best conditions for stability in design or manufacturing process, whereas the noise factors denote all factors that cause variation [13]. According to Taguchi based methodology, the characteristic that the larger value indicates better machining performance, such as MRR is addressed as the-larger-the better type problem and smaller value indicates the better machining performance, such as SR, Surface roughness, Wire Tension and Dimensional deviation are addressed as the-smaller-the-better type of problem.

The experiments were carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT) of Electronica Machine Tools Ltd. Using Super Ni-718 as a work piece material with dimensions as 120 x 100 x 16 mm. Zinc coated brass wire of 0.25 mm diameter is used as a tool electrode with deionized water as a dielectric. The different process parameters used in experiments were shown in Table 1 whereas Fig. 1 shows the details of experimental setup.

Table: 1. Process parameters and their levels for WEDM Process

S. No	Parameter	Symbol	Level-1	Level-II	Level-III
1	Pulse on time (A)	TON(μ s)	105	115	120
2	Pulse off time (B)	TOFF(μ s)	50	55	60
3	Wire tension (C)	WT (Kgf)	4	8	12
4	Spark gap voltage (D)	SV(volts)	20	25	30



Figure: 2. Experimental setup

IV. RESULTS AND DISCUSSIONS

In this work, eight experiments based on Taguchi (L8) DOE were conducted (Ref. Table 2) and results were obtained for MRR, SR, WT and dimensional deviation. The statistical software, Minitab 16 was used and the results obtained for

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all the experimental runs were statistically analyzed using analysis of variance (ANOVA) at 95 % confidence level and the effects of the selected variable were evaluated.

Table: 2. Orthogonal array L9

Experiment No	TON	TOFF	WT	SV
1	105	50	4	20
2	105	55	8	25
3	105	60	12	30
4	115	50	8	30
5	115	55	12	20
6	115	60	4	25
7	120	50	12	25
8	120	55	4	30
9	120	60	8	20

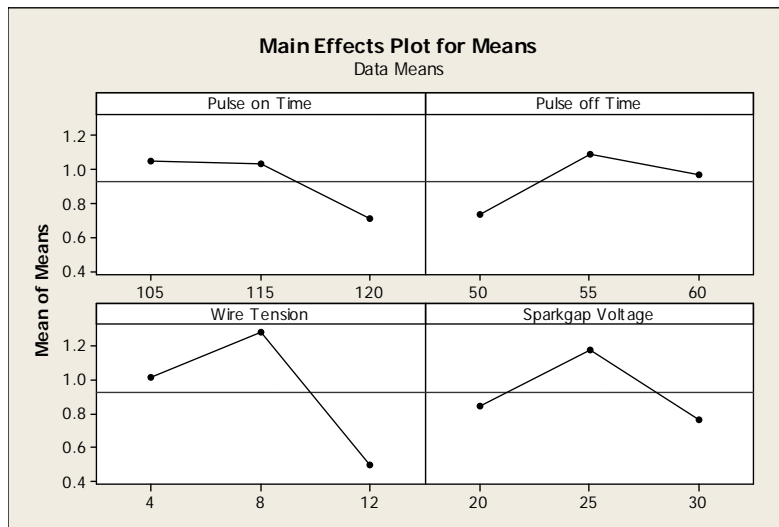


Figure: 3. Main Effects Plot for MRR

Table: 3. ln(MRR) versus ln(Ton), ln(Toff), ln(WT), ln(SV): Regression Analysis

$$\ln(\text{MRR}) = 5.0 - 2.09 \ln(\text{Ton}) + 1.66 \ln(\text{Toff}) - 0.546 \ln(\text{WT}) - 0.29 \ln(\text{SV})$$

Predictor	Coefficient	SE coefficient	T	P
Constant	5.04	19.48	0.26	0.808
ln (Ton)	-2.086	3.414	-0.61	0.574
ln (Toff)	1.657	2.554	0.65	0.552
ln (WT)	-0.5457	0.4192	-1.30	0.263
ln (SV)	-0.288	1.147	-0.25	0.814

S = 0.570497 R-Sq = 38.9% R-Sq(adj) = 0.0%

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Table: 4. Analysis of variance

Source	DF	Sum of Squares	Means sum of squares	F	P
Regression	4	0.8305	0.2076	0.64	0.663
Residual error	4	1.3019	0.3255		
Total	8	2.1323			

DF-Degree of freedom, SS- Sum of squares, MS- Mean squares, F-Ratio of variance, P-determines significance of a factor at 95% confident level.

Fig. 3 shows the main effects of plot for MRR versus pulse-on time (TON), pulse-off time (TOFF), wire tension (WT) and spark gap set voltage (SV). According to this figure, MRR increases with increase in pulse-on time and wire tension. High pulse-on time (TON) results in faster erosion of the material as longer duration of spark results in higher spark energy release hence increase in MRR was observed. Machining speed increases with decrease in spark gap set voltage value. Increasing spark gap set voltage increases the spark gap which fails in ionization of dielectric fluid and consequently MRR decreases. Increasing wire tension does not confirm any significant effect on MRR.

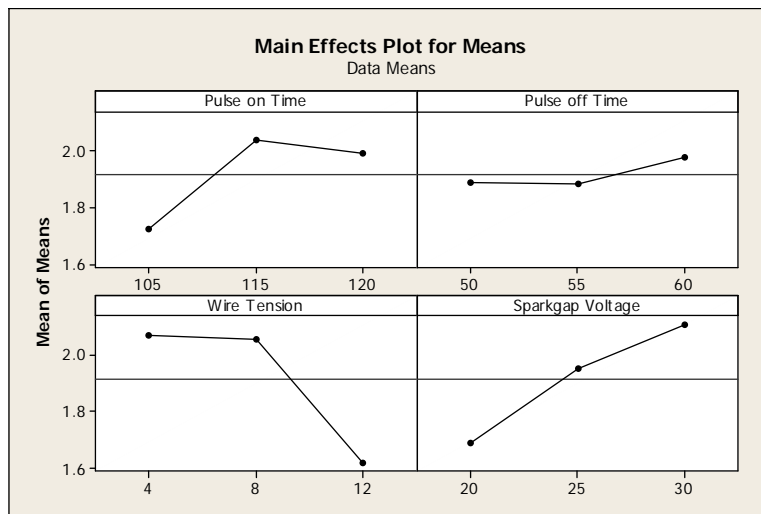


Figure : 4. Main effects plot for Surface roughness

Table: 5. ln(Ra) versus ln(Ton), ln(Toff), ln(WT), ln(SV) : Regression Analysis

$$\ln(Ra) = - 7.20 + 1.13 \ln(Ton) + 0.282 \ln(Toff) - 0.190 \ln(WT) + 0.542 \ln(SV)$$

predictor	Coefficient	SE coefficient	T	P
Constant	-7.201	3.890	-1.85	0.138
ln (Ton)	1.1314	0.6817	1.66	0.172
ln (Toff)	0.2817	0.5099	0.55	0.610
ln (WT)	-0.19019	0.08370	-2.27	0.086
ln (SV)	0.5420	0.2290	2.37	0.077

S = 0.113899 R-Sq = 77.6% R-Sq(adj) = 55.1%

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Table: 6. Analysis of Variance

Source	DF	Sum of Squares	Means sum of squares	F	P
Regression	4	0.17936	0.04484	3.46	0.128
Residual error	4	0.05189	0.01297		
Total	8	0.23125			

Fig. 4 shows increasing pulse-on time and Surface roughness increases. This is due to increase of pulse duration means discharge will last a longer time, which leads to a higher discharge energy. while pulse duration was kept constant, an increase in discharge current would also increase discharge energy which affects Surface roughness by increase in diameter and depth of the discharging craters.

Surface roughness were observed to be improving with pulse-off time, wire tension and spark gap set voltage. As wire tension increases, vibration reduces and improves surface quality. So, the only development factor were observed as wire tension. This is due to wire tension increases, vibration reduces.

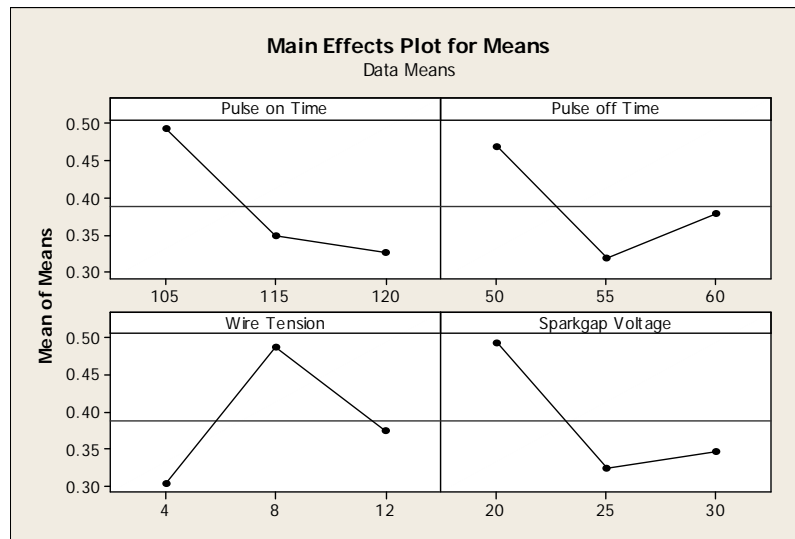


Figure: 5. Main Effects Plot for Dimensional Deviation

Table: 7. ln(DD) versus ln(Ton), ln(Toff), ln(WT), ln(SV) : Regression Analysis

$$\ln(DD) = 28.0 - 4.21 \ln(\text{Ton}) - 1.54 \ln(\text{Toff}) + 0.451 \ln(\text{WT}) - 1.22 \ln(\text{SV})$$

Predictor	coefficient	SE coefficient	T	P
Constant	28.03	14.06	1.99	0.117
ln (Ton)	-4.208	2.465	-1.71	0.163
ln (Toff)	-1.537	1.844	-0.83	0.451
ln (WT)	0.4509	0.3026	1.49	0.210
ln (SV)	-1.2201	0.8279	-1.47	0.215

S = 0.411813 R-Sq = 66.7% R-Sq(adj) = 33.3%

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Table: 8. Analysis of variance

Source	DF	Sum of Squares	Means sum of squares	F	P
Regression	4	1.3571	0.3393	2.00	0.259
Residual error	4	0.6784	0.1696		
Total	8	2.0355			

Figure 5. shows the main effects of plot for dimensional deviation which explains that increment in pulse-on time, pulse off time and spark voltage have an effect on dimensional deviation whereas it improves with increment in wire tension. Dimensional deviation value increases if the energy contained in a pulse increases to a larger value. Therefore, when pulse on time is very high the dimensional deviation increases.

V. CONCLUSIONS

In this study, the effect of process parameters in WEDM response variables (MRR, SR, WT and Dimensional Deviation) of Super Ni- 718 was investigated. Selection of orthogonal array levels of input parameters have been investigated experimentally in WEDM process(TON, TOFF, SV and WT). This research varies the input process parameters of WEDM process in the pulse on time of process performance of cutting rate, surface roughness and dimensional deviation. Increase of pulse duration causes higher discharge energy and also increase in discharge current causes increase of discharge energy which affects MRR by increasing in diameter and depth of the discharge craters. Surface roughness improves with increase in pulse-off time, wire tension and spark gap voltage. Dimensional deviation is affected by increase in pulse on time, pulse off time and spark gap set voltage. However, increasing wire tension is found to be improving dimensional deviation.

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