ISSN No.: 2455-6130
Volume 2, Issue 3, 2017, pp. 06-14

website: www.ijoetr.com

International Journal of Emerging Trends in Research

Wire EDM of Nimonic-80A Alloy: A Study on Surface Roughness using Taguchi Method

Yogesh Bhardwaj[1], Er. S. K. Sharma[2]

[1]*M.Tech. Scholar, Department of Mechanical Engineering, YIET, Yamuna Nagar, Haryana, India*

[2]*Associate Professor, Department of Mechanical Engineering, YIET, Yamuna Nagar, Haryana, India*

Abstract

In this current research work, experiments have been performed on *Nimonic-80A alloy* using Wire EDM process by employing Taguchi's method in form of L9 orthogonal array in order to design the experiments. Surface roughness has been experimentally studied and analyzed by using Analysis of Variance. Different process variables investigated are; pulse on-time (T_{on}), pulse off-time (T_{off}), and spark gap voltage (SV). All the studied parameters have been revealed to be significant for the explored machining response i.e. surface roughness. The optimum setting for surface roughness is; pulse on-time (T_{on}) is 108 µs, pulse off-time (T_{off}) is 55 µs, and spark gap voltage (SV) is 70 V.

Keywords: SR, nimonic alloy, spark gap, taguchi method, WEDM.

1. Introduction

The wire cut electric discharge machining (WEDM) process is a thermal type non-traditional machining method. WEDM process performs the machining of electrically conductive workpiece with the help of electro-thermal energy developed in the machining zone, consisting of the gap between continuously moving wire and workpiece flushed with dielectric. The plasma channel is built up across the machining gap due to ionization of dielectric. High frequency pulses of AC or DC current developed between wire and workpiece cause higher amount of heat energy responsible for melting and evaporation of the workpiece resulting in formation of craters. This further helps the material to be removed out from the base surface.

Haron C. H. [1] explored the tool life and surface integrity in turning of titanium alloy (Ti-6Al-2Sn-4Zr-6Mo). Experiments were performed on turning of Ti alloy and subsequently tool life was measured using optical microscope. Results showed that inserts with fine grain size have a longer tool life.

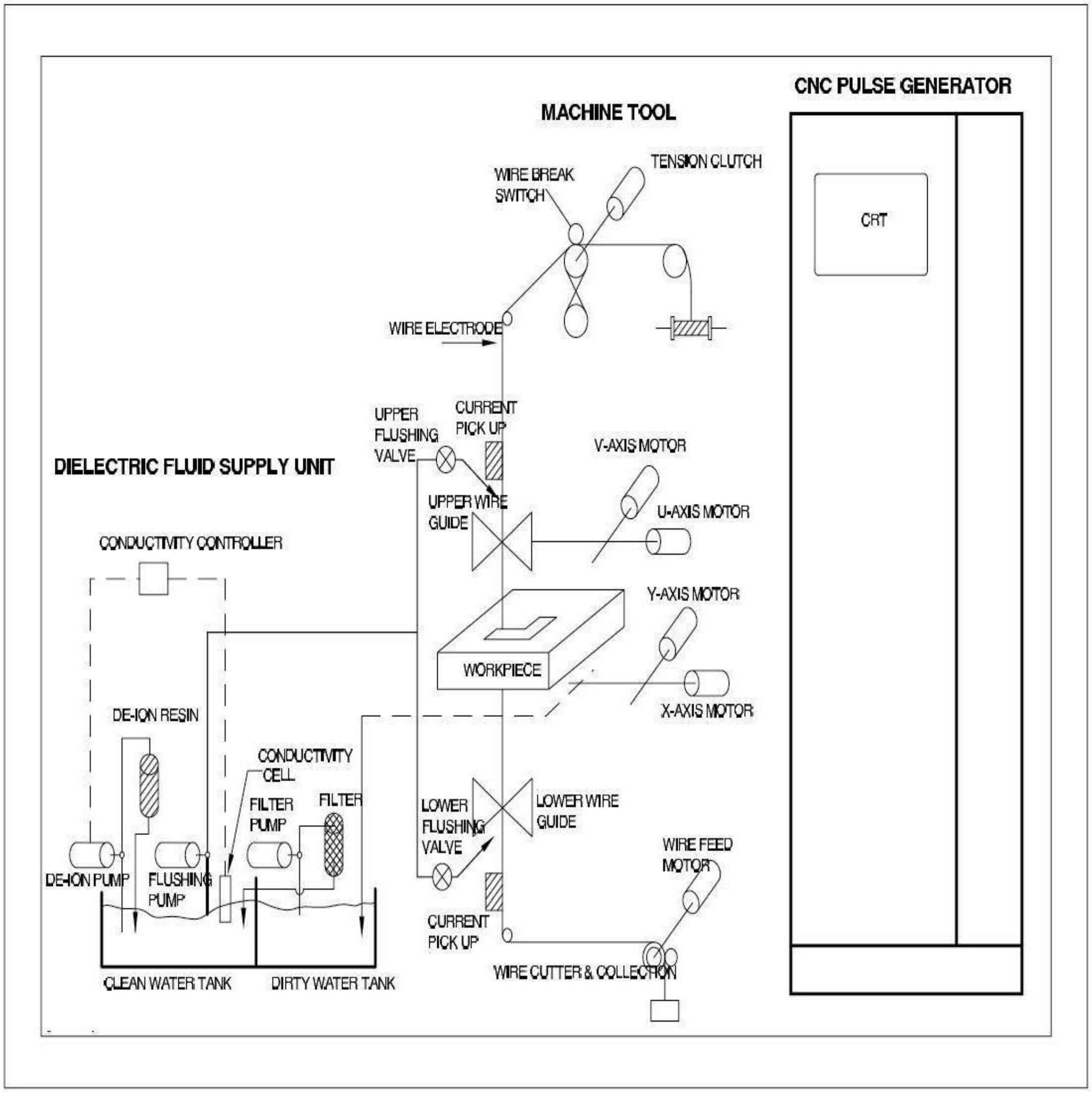


Figure 1 Set-up of WEDM process

It was concluded that straight grade cemented carbides are most suitable for machining Ti alloy and the dominant wear mechanisms for cemented WC-CO tools are dissolution and diffusion. Severe plastic flow, tearing and deformation were also observed. Tosun et al. [2] investigated the effect of pulse duration, open circuit voltage, wire speed, and dielectric flushing pressure on Kerf and Material removal rate (MRR) using Taguchi's experimental design and ANOVA test for AISI 4140 steel as work material. The results showed that open circuit voltage and pulse duration are highly influential parameters for machining characteristics considered. The multi-objective optimization methodology was adopted for achieving optimal conditions which revealed that low kerf and high MRR could be achieved by considering equal weightage for both machining characteristics. Similar studies [3-6] have also reported a comparison of the machinability of Ti alloy (Ti-6Al-4V and Ti-5Al-5Mo-5V). Machinability of Ti-5Al-5Mo-5V was found to be poor as compared to Ti-6Al-4V. A close relationship was observed between machinability rating and mechanical properties of work material, tool wear and component forces. Fang and Wu reported the comparative study of cutting forces in high speed machining of Ti-6Al-4V and Inconel 718 with a round cutting edge tool. It was reported that cutting force and thrust force consumption are higher for Inconel 718 than Ti-6Al-4V alloy due to higher shear strength of Inconel 718. The parametric optimization of machining responses helps to solve real life industrial problems [7-18].

2. Experimentation

The experimentation work was performed on a four-axis CNC type wire cut electrical discharge machine (make-Electronica). For the present research work, a rectangular piece of Nimonic-80A alloy was chosen as work material. The workpiece utilized for machining was having dimensions of 120 mm × 100 mm × 20 mm. The following parameters were selected for the study based on the availability of these parameters.

1. **Pulse on time**
2. **Pulse off time**
3. **Spark gap voltage**

The other parameters were made to be fixed during experimentation.

TABLE 1: PARAMETERS USED ON WEDM SET-UP

Control factor	Symbol
Pulse on time (T_{ON})	Factor A
Pulse off time (T_{OFF})	Factor B
Spark gap voltage (SV)	Factor C

In this experimental study, each control factor used having three levels. Details of each factor level are shown below in Table 2:

TABLE 2: VARIOUS FACTORS AND THEIR LEVELS (MACHINE UNIT)

S. No.	Symbol	Factors	Level 1	Level 2	Level 3	Unit
1	A	T_{ON}	108	115	122	µs
2	B	T_{OFF}	35	45	55	µs
3	C	Spark Gap Voltage	30	50	70	V

Taguchi's L9 orthogonal array has been used for designing the experimentation. The whole experimentation replicated twice and the mean value of responses has been provided here.

TABLE 3: CONTROL LOG FOR EXPERIMENT

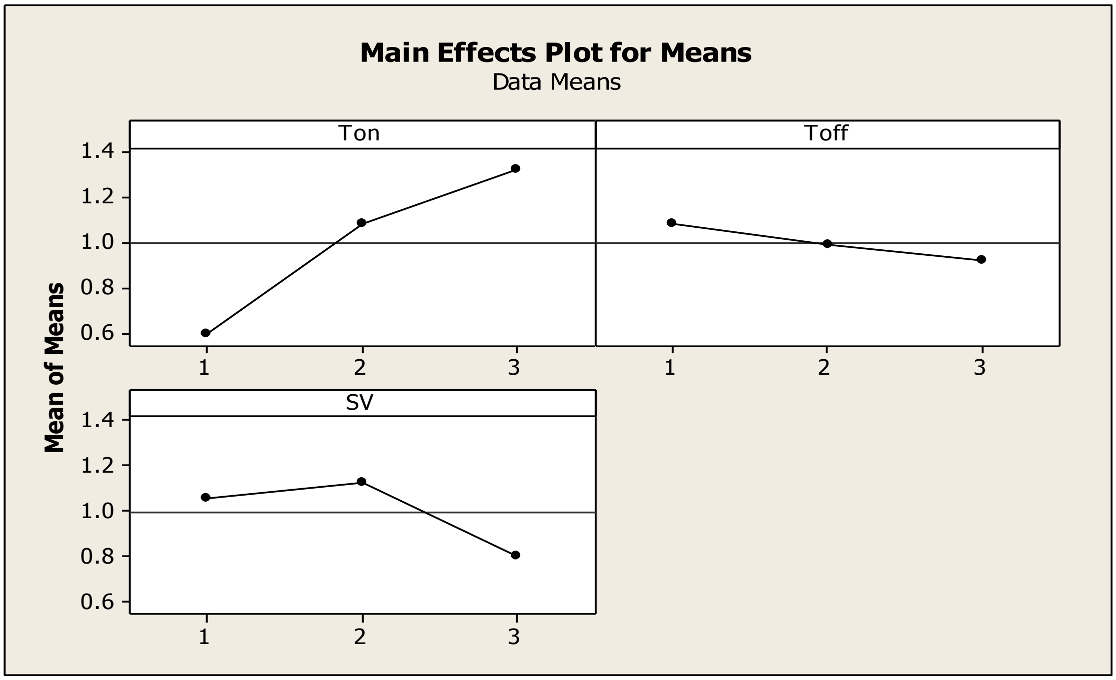
Experiment No.	Factors		
	T_{ON}	T_{OFF}	Spark Gap Voltage (SV)
1	108	35	30
2	108	45	50
3	108	55	70
4	115	35	50
5	115	45	70
6	115	55	30
7	122	35	70
8	122	45	30
9	122	55	50

TABLE 4: TEST DATA FOR SURFACE ROUGHNESS (SR)

Exp. No.	T_{ON}	T_{OFF}	Spark Gap Voltage (SV)	SR mean value (µm)	SR S/N ratio (db)
1	108	35	30	0.7314	2.716897
2	108	45	50	0.775	2.213962
3	108	55	70	0.265	11.53286
4	115	35	50	1.2424	-1.88524
5	115	45	70	0.88065	1.103918
6	115	55	30	1.11	-0.90675
7	122	35	70	1.26815	-2.06369
8	122	45	30	1.315	-2.37872
9	122	55	50	1.36765	-2.71975

3. Results and Discussions

It can be seen for the figure 2 that, pulse on-time (T_{on}), pulse off-time (T_{off}), and spark gap voltage (SV) affect the surface roughness (SR), significantly.



Optimized Parametric Setting: A1 B3 C3

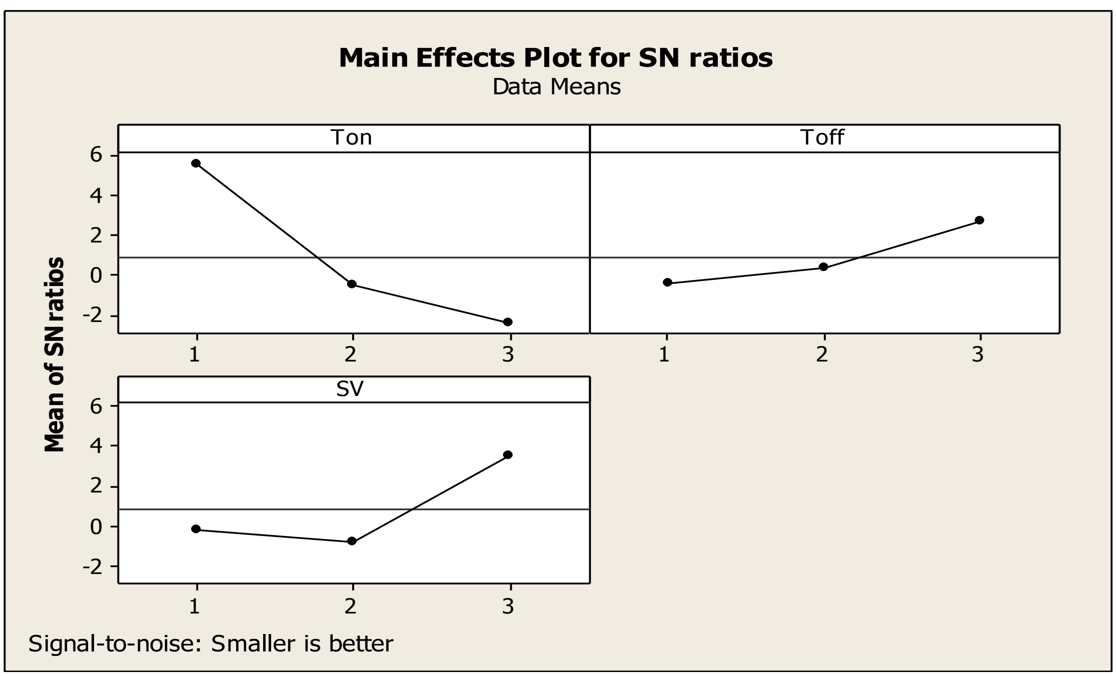


Figure 2: Mean Effect Plots for *Surface Roughness (SR)* - raw data and S/N ratio

The different input parameters used in the experimentation can be ranked in order of decreasing effect as; pulse on-time (T_{on}), spark gap voltage (SV), and pulse off-time (T_{off}).

For mean value of responses, the percentage contribution of pulse on-time (T_{on}) is 77.98 %, spark gap voltage (SV) is 16.30 %, and for the pulse off-time (T_{off}) the contribution is only 3.95 % with regard to SR.

The analyses of variance test results showed that the **A1 B3 C3** is the optimal parameters setting for the surface roughness (SR). In the study we concluded that, the input parameters setting for the, ***pulse on-time (T_{on}) is 108 µs, pulse off-time (T_{off}) is 55 µs, and spark gap voltage (SV) is 70 V***, while WEDM of *Nimonic-80A alloy* as far as the SR is concerned.

TABLE 5: ANOVA RESULTS FOR SURFACE ROUGHNESS (SR) (RAW DATA)

Source	dof	Seq. SS	Adj. SS	Adj. MS	F	P	% Contribution
T_{ON}	2	1.64475	1.64475	0.82237	242.34	0.000	77.98%
T_{OFF}	2	0.08331	0.08331	0.04165	12.27	0.002	3.95%
SV	2	0.34379	0.34379	0.17190	50.65	0.000	16.30%
Error	11	0.03733	0.03733	0.00339			1.77%
Total	17	2.10918					

4. Prediction of Mean

The estimate of the mean (µ) is only a point estimate based on the average of results obtained from the experiment. It is therefore customary to represent the values of a statistical parameter as a range within which it is likely to fall, for a given level of confidence (Ross, 1996). This range is termed as the confidence interval (CI). In other words, the confidence interval is a maximum and minimum value between which the true average should fall at some stated percentage of confidence (Ross, 1996).

The Taguchi approach for predicting the mean performance characteristics and determination of confidence interval for the predicted mean has been applied. The average value of performance characteristics obtained through the confirmation experiments must be within the 95% confidence interval (α= 0.05).

For calculation of CI_{CE}, the following equation has been used.

$$CI_{ce}=\sqrt{Fa(1,fe)Ve\left[\frac{1}{neff}+\frac{1}{R}\right]} \qquad \text{……. (5.1)}$$

Where $Fa(1, fe)$ =the F ratio at a confidence level of against DOF 1, and error degree of freedom f_e.

$$n_{eff} = \frac{N}{1+[Total\ DOF\ associated\ in\ the\ estimate\ of\ the\ mean]}$$

N = Total number of results

R = Sample size for confirmation experiment

Ve = error variance

For ***Surface Roughness (SR);***

T_{on}, T_{off}, and SV are identified as the significant factors for the surface roughness. Hence, the predicted (optimal) value of SR is computed using Minitab 16.

μ_{SR} = 0.3192 (using Minitab 16)

Fa = 4.84

Ve = 0.00339 (from ANOVA results)

n_{eff} = 2.5714

N = No. of experiments conducted in total (9×2 = 18)

R = 2

Hence, putting all the values in equation (5.1)

$CI_{CE(SR)} = \pm 0.1295$

The 95% confidence level for μ_{SR} is

$CI_{CE (SR)} = 0.1897 < \mu_{SR} < 0.4487$

The predicted optimum values and the confidence interval have been tabulated in table 6. Experiments were conducted at optimum setting of process parameters for all the response factors.

TABLE 6: COMPARISON OF PREDICTION AND EXPERIMENTAL RESULTS FOR SR

RESPONSE		PREDICTED VALUE	EXPERIMENTAL VALUE	CI_{CE}
SR	µm	0.3192	0.3521	$0.1897 < \mu_{SR} < 0.4487$

This could be observed from the table 6 that, the values from the confirmation experiments were contained well within the confidence interval for MRR. Hence, the optimization results were validated.

5. CONCLUSION

Based on the experiments conducted the following conclusions have been drawn:

1. Pulse on-time (Ton), and Spark gap voltage (SV) significantly affects the ***Surface Roughness (SR)*** in Wire EDM of Nimonic-80A alloy. With regarding to the average response T_{on} and SV are more significant as compare to Pulse off-time (T_{off}).

2. For mean value of responses, the percentage contribution of pulse on-time (T_{on}) is 77.98 %, spark gap voltage (SV) is 16.30 %, and for the pulse off-time (T_{off}) the contribution is only 3.95 % with regard to SR.
3. The analyses of variance test results showed that the **A1 B3 C3** is the optimal parameters setting for the surface roughness (SR). In the study we concluded that, the input parameters setting for the, **pulse on-time (T_{on}) is 108 μs, pulse off-time (T_{off}) is 55 μs,** and **spark gap voltage (SV) is 70 V**, while WEDM of Nimonic-80A alloy as far as the SR is concerned.

References

1. Haron C.H. (2001), "Tool life and surface integrity in turning titanium alloy", *Journal of Materials Processing Technology*, Vol. 118 (1-3):231-237.
2. Tosun N., Cogun C. and Tosun G. (2004), "A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method", *Journal of Materials Processing Technology*, Vol.152(3):316-322.
3. Tzeng C.J., Yang Y.K., Hseigh M.H. and Jeng M.C. (2010), "Optimization of wire electrical discharge machining of pure Tungsten using neural network and response surface methodology", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, Vol.225(6):841–852.
4. Bamberg E. and Rakwal D. (2008), "Experimental investigation of wire electrical discharge machining of gallium-doped germanium", *Journal of Materials Processing Technology*, Vol. 197(1-3):419-427.
5. Masuzawa T., Kuo C.L. and Fujino M. (1994), "A combined electrical machining process for micro nozzle fabrication." *Ann. CIRP*, Vol. 43(1):189-192.
6. Mendes L.A., Amorim F.L. and Weingaertner W.L. (2015), "Automated system for the measurement of spark current and electric voltage in wire EDM performance", *Journal of Brazilian Society of Mechanical Science and Engineering*, Vol.37(1):123–131, DOI: 10.1007/s40430-014-0171-x.
7. Singh RP and Singhal S. Experimental investigation of machining characteristics in rotary ultrasonic machining of quartz ceramic. *Proc IMechE, Part L: J Materials: Design and Applications* 2016; 1–20. DOI: 10.1177/1464420716653422.
8. Singh RP and Singhal S. Investigation of machining characteristics in rotary ultrasonic machining of alumina ceramic. *Mater Manuf Process* 2016; DOI: 10.1080/10426914.2016.1176190.
9. Singh RP and Singhal S. Rotary ultrasonic machining: a review. *Mater Manuf Process* 2016; 1–30. DOI: 10.1080/10426914.2016.1140188.
10. Kataria R, Kumar J and Pabla BS. Experimental investigation and optimization of machining characteristics in ultrasonic machining of WC-Co composite using GRA method. *Mater Manuf Process* 2016; 31: 685–693.

11. Singh, R.P., Kumar, J., Kataria, R., Singhal, S. (2015) ‘Investigation of the machinability of commercially pure titanium in ultrasonic machining using graph theory and matrix method’, Journal of Engineering Research, Vol. 3, Issue 4, pp.75-94.
12. Kataria, R., Kumar, J. (2014). A comparison of the different multiple response optimization techniques for turning operation of AISI O1 tool steel. *Journal of Engineering Research*, *2*(4), 1-24.
13. Kataria, R., Kumar, J., & Pabla, B. S. (2015). Experimental Investigation into the Hole Quality in Ultrasonic Machining of WC-Co Composite. *Materials and Manufacturing Processes*, *30*(7), 921-933.
14. Singh, R.P., and Singhal, S., (2015) Rotary ultrasonic machining of advanced materials: a review. International Journal for Technological Research in Engineering, 2(7), 777-785.
15. Gautam, V., Singh, R. P., Kataria, R., & Kumar, J. (2016). A Critical Review on the Impact of Input Factors on Process Outcomes in Drilling of Aluminium Alloys. International Journal of Emerging Trends in Research, 1(1), 12-18.
16. Kumar, G., Rajneesh, Singh, R. P., Kataria, R. (2016). Employability of biogas & bio-slurry with algae and cow dung as substrates for continuous advancement. *International Journal of Emerging Trends in Research*, 1(1), 19-25.
17. Dipesh. (2016). Non traditional machining: a review. *International Journal of Emerging Trends in Research*, 1(1), 26-32.
18. Balasubramanian S. and Ganapathy S. (2015), “Study on the Material removal mechanism in Wire Electrical Discharge Machining”, *International Journal of Engineering Technology, Management and Applied Sciences*, Vol.3 (Special issue): 20-27, ISSN 2349-4476.