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Optimization of surface roughness by design of experiment techniques during wire EDM machining

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A B S T R A C T

Wire EDM technique has been often employed in fabricating electrically conductive difficult to cut metal complex shape components with high tolerance and precision. In WEDM process, generally employed conventional brass wire electrode is employed for machining operation. In this study we have employed zinc coated brass wire electrode for enhanced machining speed, accuracy, and precision. To investigate the variation in process parameters, i.e. peak current (Ip), pulse on time (Ton), pulse off time (Toff) and feed rate (FR) with optimization during WEDM machining operation. The obtained results have optimized by the Taguchi's methodology. ANOVA analyses reveal critical factors for improvement of surface roughness. In this study, it was concluded that surface roughness increases with decrease in pulse off time, and spark gap set voltage. The surface roughness on the sample was enhanced with increase in Ton and IP.

1. Introduction

Unconventional machining process are often called as advanced machining processes as they have been established in modern-day productions. In these unconventional metal removal process, energy utilized in employing removal of material from the workpiece include from, mechanical, heat energy, electrical energy, or chemical reactions or combinations of these resources. Conventional machining processes are not appropriate methods to machine difficult to machine workpieces [1,2]. Conventional machining processes possesses lot of problems in machining such difficult-to-cut materials. In metal removal process, very hard materials, conventional processes would not be viable, adequate, or efficient. EDM employs a thermo-electrical process, during which material is chipped off from work piece by utilizing thermal energy of spark generation. Wire EDM is an advanced machining process that is employed to fabricate difficult to cut, electrically conductive hard metal components with complex geometry having high tolerance, accuracy, and precision [3-5]. Nimonic 80A has excellent mechanical properties and high corrosion resistance and thus making it as a widely employed in biomedical, automobile, aerospace applications. The superiority of engineering components is often evaluated with surface roughness, an important machining factor. Huge thermal energy generated during WEDM results in change in microstructure and its composition of material and leads to formation of individual oxide (OH) layer over the surface. Hence, machining Nimonic material to superior quality, higher surface finish and great accuracy pose as a challenge for most of the industries and researchers. Prohaszka et al. [6] examined the usage of electrode material in enhancing performance of WEDM. It was observed that the efficiency of cutting of electrode made with magnesium was higher than zinc electrode. Puri and Bhattacharyya [4] observed the influence of cutting speed, wire lag along with other parameters of machining and machine has effect on geometrical inaccuracy. It was noted that, for least inaccuracy in geometry, the variation between offset values during initial rough cut and finish cut must as maximum feasible. Puertas et al. observed the impact of factors on surface roughness on cobalt-bonded cemented carbide (WC-Co). The rise in surface roughness was observed as the pulse time or intensity increased. Chiang and Chang [7] had optimized the WEDM for various performance attributes. The surface roughness was found to decrease from 3.214 to 2.051 μm during the process. Sarkar et al [8] has

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Table 1
Selected factors and levels.

Levels	Factors			
	A	B	C	D
1	6	0.7	4	5
2	7	0.9	5	7
3	8	1.1	6	9

Table 2
Summary of Orthogonal array.

S. no.	A	B	C	D	Surface roughness (μm)
1	6	0.7	4	5	2.446
2	6	0.9	5	7	2.694
3	6	1.1	6	9	2.943
4	7	0.7	5	9	2.440
5	7	0.9	6	5	2.675
6	7	1.1	4	7	2.976
7	8	0.7	6	7	2.420
8	8	0.9	4	9	2.721
9	8	1.1	5	5	2.956

observed that, greater cutting speed leads in increased surface roughness during machining process of titanium aluminide in WEDM. The investigation of machining response of wire EDM has been performed. The various optimization techniques like Taguchi's, RSM, ANN etc. has used to analysis the process parameters of wire EDM techniques [9-12].

2. Materials

The electronically operated wire EDM was employed in conducting machining operations over the sample. The Nimonic 80A was employed as workpiece material and it contains, 77.05 wt% of nickel, 18.39 wt% chromium, 1.92 wt% titanium, 1.05 wt% aluminium, 0.63% wt% iron and remaining traces of manganese and silicon. Electrode wire made of high-speed brass and brass wire coated with zinc were used as wire elected materials of diameter 0.25 mm. Table 1 shows the selected levels and factors for the process. The output parameters from the WEDM process were observed is surface roughness (SR). In this research to examine the SR, Surfcom 130/480A was employed to observe the cut samples. Scanning electron microscopy images were taken to explore the microstructure of machined samples.

Table 3
Response table for surface roughness.

Levels	A	B	C	D
1	−8.584	−7.730	−8.644	−8.576
2	−8.588	−8.617	−8.590	−5.586
3	−8.596	−9.421	−8.532	−8.606
Delta	0.011	1.691	0.114	0.029
Rank	4	1	2	3

3. Results and discussions

In Wire EDM technique, peak current (A), pulse on time (B), pulse off time(C) and feed rate (D) affect the functioning of the machining operation over a sample. WEDM process was experimentally solved in this study for wire cutting of using Design of experiment techniques. Table 2 shows the orthogonal array and Table 3 shows the response table.

In this study the Taguchi's method has been employed in evaluating the influence of surface roughness due to four input parameters as process parameters. Response table for surface roughness shows that the input parameter Ton is most important parameter for surface roughness for both S/N ratio (Fig. 1). Rank for the response is also provided to indicate the significance of the factors in this study. Furthermore, least important parameter being Toff, and Ip of surface roughness. Response plots of combinations are revealed. The top set of parameters should be evaluated by choosing levels with high S/N ratio from the Table 3 as highlighted.

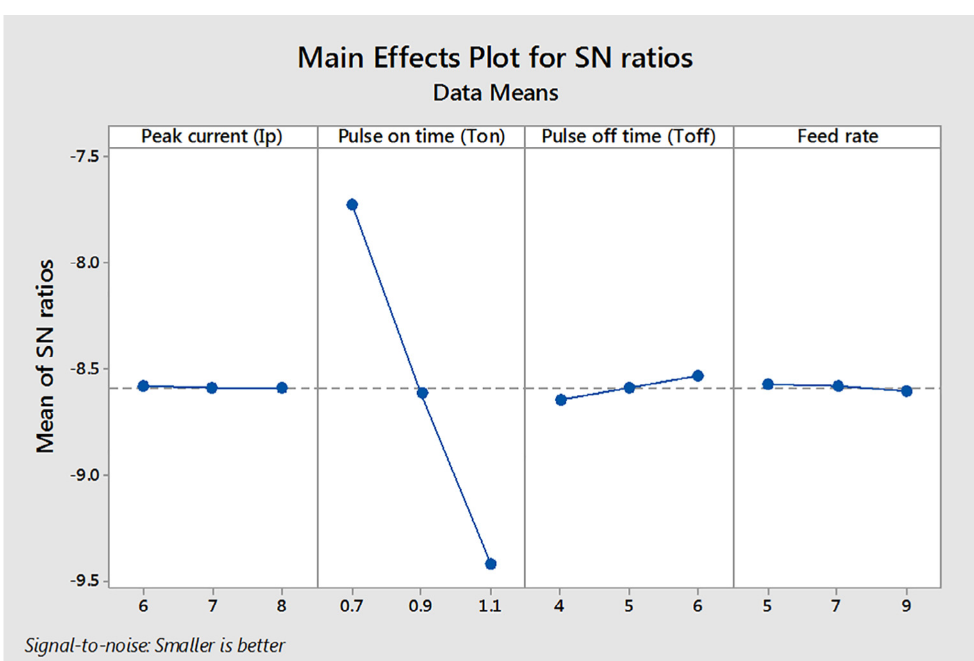

Fig 1. S/N ratio (smaller is better) for surface roughness.

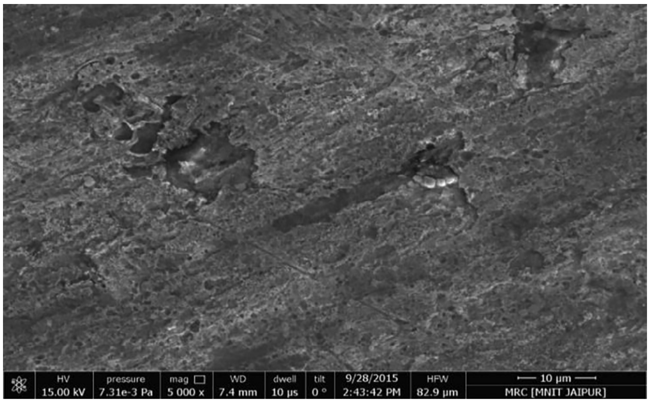

Fig 2. SEM image of fabricated sample using WEDM.

After Taguchi analysis was employed to the results, it is noted that pulse on time was most responsible and influential on surface roughness during the experimental work for this study.

4. SEM analysis

Scanning Electron Microscopy was done on samples to distinguish the effect of brass wire WEDM process. SEM images (Fig. 2) reveal the surface integrity of the sample and depicts the surface roughness, size and depth of the ridges and valleys, geometrical size of recast layer and heat affected zone over Nimonic 80A sample workpiece**.**

5. Conclusions

Nimonic 80A alloy is relatively machinable material using wire EDM process. The breakage of the wire during the WEDM machining operation is an important parameter effecting the performance of WEDM operation conditions such a surface roughness. Hence a zinc coated brass wire was employed for the machining operation. Taguchi method (DOE technique) was employed to determine the effect of surface roughness due to four input process parameters. Signal to noise ratio was easy method to calculate the impact of factors according to their levels. Response table for surface roughness depicts that input parameter pulse on time was significant parameter for roughness for both type of S/N ratio. Rank was also given (based on response table) to locate importance of factors of this study.

CRediT authorship contribution statement

Ashish Goyal: Conceptualization, Methodology. **Adithya Garimella:** Data curation, Writing - original draft. **Priyanka Saini:** Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References:

[1] G. Wollenberg, H.P. Schulze, M. Läuter. Process energy supply for unconventional machining. In Proc. Intern. Symp. Electromachining (ISEM-XIII). Spain (2001) (pp. 220-232).
[2] M.Y. Khan, P. Sudhakar Rao, Optimization of process parameters of electrical discharge machining process for performance improvement, Int. J. Innov. Technol. Explor. Eng. 8 (11) (2019) 3830–3836.
[3] K.H. Ho, S.T. Newman, S. Rahimifard, R.D. Allen, State of the art in wire electrical discharge machining (WEDM), Int. J. Mach. Tools Manuf. 44 (12-13) (2004) 1247–1259.
[4] A.B. Puri, B. Bhattacharyya, An analysis and optimisation of the geometrical inaccuracy due to wire lag phenomenon in WEDM, Int. J. Mach. Tools Manuf. 43 (2) (2003) 151–159.
[5] S.S. Mahapatra, A. Patnaik, Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, Int. J. Adv. Manuf. Technol. 34 (9-10) (2007) 911–925.
[6] J. Prohaszka, A.G. Mamalis, N.M. Vaxevanidis, The effect of electrode material on machinabilitys in wire electro-discharge machining, J. Mater. Process. Technol. 69 (1–3) (1997) 233–237.
[7] K.-T. Chiang, F.-P. Chang, Optimization of the WEDM process of particle-reinforced material with multiple performance characteristics using grey relational analysis, J. Mater. Process. Technol. 180 (1-3) (2006) 96–101.
[8] S. Sarkar, M. Sekh, S. Mitra, B. Bhattacharyya, A novel method of determination of wire lag for enhanced profile accuracy in WEDM, Precis. Eng. 35 (2) (2011) 339–347.
[9] A. Goyal, H.U. Rahman, S.A.C. Ghani, Experimental investigation & optimisation of wire electrical discharge machining process parameters for Ni49Ti51 shape memory alloy, J. King Saud Univ.-Eng. Sci. (2020).
[10] A. Goyal, A. Pandey, P. Sharma. Investigation of surface roughness for Inconel 625 using wire electric discharge machining. In IOP Conference Series: Materials Science and Engineering Vol. 377, No. 1 2018 p. 012109. IOP Publishing.
[11] A. Pandey, A. Goyal, R. Meghvanshi, Experimental investigation and optimization of machining parameters of aerospace material using Taguchi's DOE approach, Mater. Today Proc. 4 (8) (2017) 7246–7251.
[12] D. Bhatt, A. Goyal, Multi-objective optimization of machining parameters in wire EDM for AISI-304, Mater. Today Proc. 18 (2019) 4227–4242.