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Machining parameters in WEDM of EN31 steel using Taguchi technique optimization

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ABSTRACT

Wire electrical discharge machining (WEDM) is often used in the machining of conductive materials when precision is important. The current study looked at wire-cut electric discharge machining of EN31 steel. Taguchi's L27 orthogonal array was used to finish the investigation using various amounts of input parameters. This method was used to determine the optimal parameter combination. The experimental findings show that the machining model is correct, and Taguchi's approach meets the practical requirements. Surfaces having micro cracks and porosity, as well as poor surface quality, are produced by rough machining with WEDM. Finish machining yields a better surface finish (Ra) but at a slower rate (MRR). As a result, the Taguchi approach's purpose is to improve MRR while lowering Ra. To check the performance measures in terms of Surface Roughness, control parameters such as voltage applied, pulse width, pulse interval, and speed were used.

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1. Introduction

Wire cut process with a Computer numerically controlled (CNC) instruments operate EDM equipment, allowing it to manage wire on a 3D axis, also adding axis of motion to the stringers allows for more complex cuts to be produced. Wire EDM equipment and services in four and five axes are provided [1]. Wire EDM's improved accuracy enables for detailed shapes and incisions, but traditional EDM can't always generate close-fitting junctions or particularly convoluted patterns. Wire EDM can also routinely cut metals as thin as 0.101 mm and larger materials up to 400 mm with thicker portions are feasible. Raise in temperature force the metal to disappear at a particular material thinness, removing any potential contaminants [2-4]. To put it another way, because the wire is surrounding by a band of current, the smallest and most exact cutting path is the extra thickness of the ring and wire, which technicians can easily account for as manufacturers make finer and finer wire to enable fewer kerfs and higher precision [2,5,6].

Due to its adaptability, manufacturers employ EDM wire cutting machine operation for a wide range of applications. Because the procedure can cut very small bits, it's frequently the best option for making small, highly detailed products that would be too delicate for other machining methods [7-9]. The procedure can cut very small bits, it's a good fit for making little, intricate products that would be too fragile for conventional machining methods [10,11]. Furthermore, the procedure is cost-effective for low-volume projects and can be useful in prototype production, even if the actual project is completed in a different way. Wire EDM is a sluggish process compared to many other machining technologies, yet speeds have improved over time due to technology advancements. By stacking identical components and cutting them all at once, throughput can be enhanced. Multi-head machines may cut numerous identical pieces at the same time [12]. The work piece may be subjected to some stresses because wire EDM is a thermal process. [13]. The servo reference, voltage, and wire tension were the three most important characteristics that influenced the cutting speed [15–18]. The main advantages of WEDM are creates simple or intricate forms or patterns that are difficult to achieve with traditional cutting tools and on a wide range of stainless steel alloys, CNC controlled cutting patterns may be completed fast while retaining a low Ra surface roughness. Wire EDM is most

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typically utilized in the manufacture of molds and dies, especially extrusion dies and blanking punches also most commonly used to make metal components and tools, and it may be utilized for everything from prototypes to complete production runs.

2. Experimental details

This activity involves milling magnesium alloy pieces with precise machine parameter settings and measuring the quality criteria listed. When compared to the quality levels attained with the initial machine parameter values, the enhanced machine factor settings noticeably increase the worth features of the machined work piece. The intricate interaction WEDM include wire cutting speed, amplitude cutting speed, wave time. The effects of rake angle, peak power, discharge current time, pulse-off time, wire stiffness, and electrical flow rate on material removal rate and surface irregularity are investigated through the complicated machining. To enhance MRR and SR at the same time, grey relational analysis (GRA) is applied in conjunction through the Taguchi method. Using GRA and the Taguchi technique on WC-Co composite, in both machining characteristics, the deviation between experimental values and expected outcomes is less than 3%.

2.1. Experimental set up

The investigational setup, the process for conducting experiments, and the Taguchi method for test planning are all covered in this part shown in Table 1 and Table 2

The studies were carried out using the ST CNC-E3 wire cut EDM machine. Steer Corporation invented this equipment, which is a numerically controlled wire EDM machine. A servo controller may control the horizontal and vertical axes of the work bench movement. The table will move 300 mm in the X path and 250 mm in the Y path. The w/p is coupled to the anode and the tool is attracted to the ground pin of the source, according to typical polarity convention.

The DOE data was used to collect experimental data to look at the impact of different EDM machining settings. Fig. 1 depicts

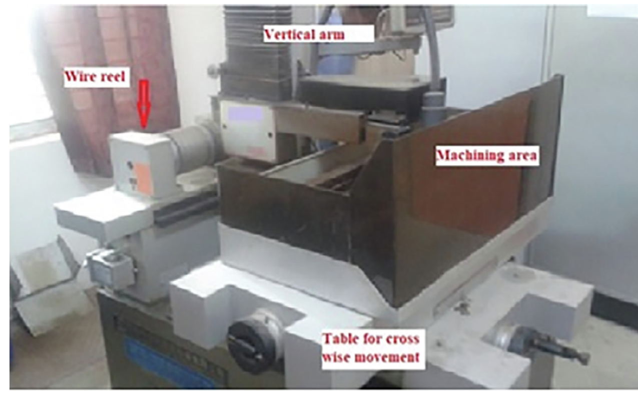

Fig. 1. Experimental setup.

the layout of wire cut EDM machine. The major goal of the research was to see how applied voltage, discharge current, pulse width, and pulse interval effect metal removal rate and surface roughness.

Fig. 2 shows path which machine travels. Two colour path have some variations. Blue colour shows where machine already travels and the yellow colour line indicates where machine yet to do the work. Fig. 3 is the actual machining process going. Whatever the strength of material the EDM process just evaporates the materials

Table 1
Setting Parameters.

Controlling variables	Symbols	Set parameter	
Voltage	A	Wire	Molybdenum wire
Pulse width	B	Shape	Rectangular product
Pulse intervalSpeed	CD	Work locationw/p on bench	Table centre
		Work piece Thickness	8 mm
		Steadiness	Servo control
		Work height	49.5 mm
		Wire type	Mo, dia – 0.19 mm

Table 2
Various control factor levels.

Level				
Control factors	1	2	3	Units
A. Applied voltage	75	90	105	Volts
B. Pulse width	5	4	5	µs
C. Pulse interval	15	25	30	µs
D. Speed	300	500	750	Rpm

Fig. 2. Machining Path Diagram.

Fig. 3. During Machining Process.

in a quick seconds time which is one of the professional advantage of it.

2.2. Experimental procedure

As a work specimen, the investigations were carried out using EN 31 alloy steel material with the following composition: (0.99% C, 0.52% Mn, 1.39% Cr & 0.21% Si). The w/p is a rectangular plate with measurements of 100x50x8 mm. Molybdenum wire with a diameter of 0.20 mm was utilised as an instrument and deionized water as a dielectric liquid to manufacture the work piece. Each sample was machined to be 4 mm in length. A stop watch was used to track machining time. The MRR and Ra values were calculated after milling and measured with a surface tester. The metre had 350 m stylus rub, 0.01 m resolution, 0.25 mm minimum cut-off, and a 2 m stylus radius. The length of the measurement was set to 3 mm.

2.3. DOE using Taguchi's technique

The WEDM process includes a muffed process, a smoothing process, and a finishing process. Various measurements are typically used to evaluate the recital of various sorts of cutting processes. Surface finish is most significant in finish cutting operations, whereas metal removal rate and surface finish are more critical in muffed cutting process. Dimensional correctness is heavily influenced by cutting breadth. This makes the muffed cutting process considerably more difficult because three objectives must be met at the same time. As a result, the muffed cutting step is examined in the current methodology, with two enactment targets in mind: MRR and Ra. The experiment is conducted using a Standard CNC-E3 wire cut EDM machine, with input settings selected from a limited set of options. In the muffed cut with finishing step, the values of response parameters that are documented. A properly developed experimental approach is necessary to explore the impact of machining factors on enactment features (MRR and Ra) and to establish the best machining settings. The testing is carried out

Table 3
The L_{27} orthogonal array was used in the experiment.

Expt. No	P	Q	R	S	MRR (mm^3/min)	S/N Ratio (db)	Ra (mμ)	S/N Ratio
1	1	1	1	1	3.318	10.4044	3.32	−10.4228
2	1	1	2	2	4.975	13.9359	3.31	−10.3966
3	1	1	3	3	2.663	8.507423	3.13	−9.91089
4	2	2	1	2	7.889	17.94044	3.64	−11.222
5	2	2	2	3	7.206	17.15389	3.42	−10.6805
6	2	2	3	1	3.810	11.6185	3.42	−10.6805
7	3	3	1	3	11.400	21.1381	3.65	−11.2459
8	3	3	2	1	6.932	16.81717	3.59	−11.1019
9	3	3	3	2	5.649	15.03943	3.75	−11.4806
10	2	3	1	2	7.130	17.06179	3.5	−10.8814
11	2	3	2	3	7.144	17.07883	3.41	−10.6551
12	2	3	3	1	7.024	16.93169	3.71	−11.3875
13	3	1	1	3	6.969	16.86341	3.37	−10.5526
14	3	1	2	1	4.002	12.04554	3.56	−11.029
15	3	1	3	2	4.580	13.21731	3.46	−10.7815
16	1	2	1	1	4.527	13.11621	3.32	−10.4228
17	1	2	2	2	2.257	7.070631	3.42	−10.6805
18	1	2	3	3	6.130	15.74921	3.34	−10.4749
19	3	2	1	3	7.999	18.06071	3.45	−10.7564
20	3	2	2	1	5.664	15.06246	3.46	−10.7815
21	3	2	3	2	4.898	13.80038	3.46	−10.7815
Expt. No	P	Q	R	S	MRR (mm^3/min)	S/N Ratio (db)	Ra (mμ)	S/N Ratio
22	1	3	1	1	4.181	12.4256	3.49	−10.8565
23	1	3	2	2	6.083	15.68236	3.63	−11.1981
24	1	3	3	3	5.690	15.10225	3.31	−10.3966
25	2	1	1	3	3.892	11.80346	3.32	−10.4228
26	2	1	2	2	5.872	15.37572	3.2	−10.103
27	2	1	3	1	3.657	11.2625	3.24	−10.2109

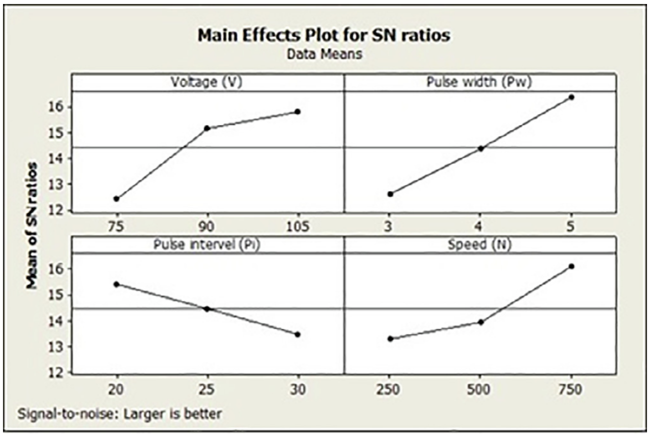

Fig. 4. Controlling factors have an impact on MRR.

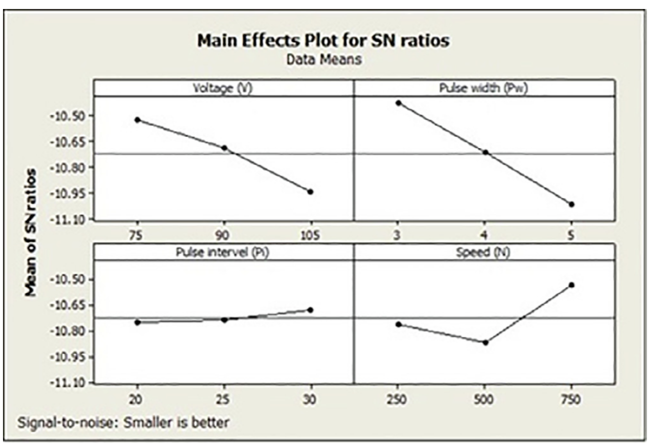

Fig. 5. Controlling factors have an impact on Ra.

using a resilient strategy and an L27 orthogonal array according to the Taguchi method. Four machining parameters – voltage applied, pulse width, pulse interval, and speed – are considered controlling factors based on the machine tool, cutting tool and work piece capability, and each parameter has three levels denoted by L1, L2, and L3, respectively. On the basis of pilot studies, the components and their relative levels were chosen. The process parameter, recital parameter, and SN ratio are shown in the table above (table 3). The higher the SN ratio, the better the machining recital, such as MRR and Ra, 'Larger-is-better,' and conversely, the lower the SN ratio, the better the machining recital, such as SR, 'smaller-is-better.'

3. Result and discussion

The influence of the four control parameters on MRR and Ra is depicted graphically in Figs. 4 and 5. MINITAB 16, a common software used for design of experiment applications, was used to conduct the study.

Table 4 and Fig. 4 respectively provide the S/N ratio reaction table and reaction graphs for MRR. The reaction table and reaction graphs for the S/N ratio for Ra are shown in Table 5 and Fig. 5. After analysing the data, it was discovered that the highest MRR is provided by factors at levels A3, B3, C1, and D3. Factor C has the least substantial result on material deletion rate and surface quality, as seen in Fig. 4, but it does have the least significant effect on taming MRR. In the same way, it is proposed to custom the components by levels $A_3B_3C_1D_3$ for Ra detraction, as revealed in Fig. 5. Features C and D have the smallest impact on Ra reduction.

Table 4
MRR S/N Ratio Reaction Table.

	P	Q	R	S
Level 1	12.42	12.59	15.42	13.30
Level 2	15.14	14.40	14.47	13.95
Level 3	15.78	16.36	13.47	16.11
Delta	3.34	3.76	1.95	2.82
Rank	2	1	4	3

Table 5
Ra S/N Ratio Reaction Table.

	P	Q	R	S
Level 1	−10.52	−10.42	−10.74	−10.77
Level 2	−10.69	−10.72	−10.74	−10.87
Level 3	−10.95	−11.02	−10.68	−10.53
Delta	0.42	0.60	0.08	0.34
Rank	2	1	4	3

Table 6
The results of the MRR confirmation experiment.

	Ideal machining parameter	
	Forecast	Observed
Level	$A_3B_3C_1D_3$	$A_3B_3C_1D_3$
MRR(mm^3/min)	8.57333	8.55

Table 7
The results of the Ra confirmation experiment.

	Ideal machining parameter	
	Forecast	Observed
Level	$A_3B_3C_1D_2$	$A_3B_3C_1D_2$
Ra(μm)	3.14326	3.11

4. Conformation study

The finest combination of machining settings remained established in previous study. Conversely, the final stage is to forecast and validate that the observed values would improve if the perfect grouping level of machining constraints were used. The assessed S/N ratios for MRR and Ra are revealed in Tables 4 and 5.

Tables 6 & Table 7 show an evaluation of forecast and observed experimental values for MRR and Ra using Minitab16′s ideal values.

5. Conclusion

The WEDM process was optimized using Taguchi's parametric design methodology in this paper. It was discovered that Taguchi's parameter strategy is a meek, efficient, consistent and competent methodology for machining parameter optimization. Through the machining of EN31 steel, the effect of various machining factors such as voltage applied, pulse width, pulse interval, and speed has been investigated. The Taguchi Optimization result was evaluated by conformation studies. It is proposed that $A_3B_3C_1D_3$ for Ra minimization is revealed.

CRediT authorship contribution statement

R. Kamalakannan: Conceptualization, Methodology. **G.M. Pradeep:** . **T. NaveenKumar:** . **M. Elango:** .

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.

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