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Application of Taguchi Method to Analysis the Influence of Technological Parameters on Surface Roughness in Electrical Discharge Wire Cutting Process

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Abstract— *Analyzing the influence of technological parameters on surface roughness in electrical discharge wire cutting is an effective method to enhance the quality of components and improve the economic feasibility and assembly capability of the product. To investigate the impact of technological parameters on surface roughness in electrical discharge wire cutting, a Taguchi L9 experimental model combined with the grey relational analysis algorithm is employed in this study. The ANOVA results reveal that in the wire cutting process for all three types of materials, the voltage (OV) has the greatest influence on surface roughness, followed by the feed rate (FR), and finally the wire feed rate (WF).*

Keywords— *Electrical discharge wire cutting, Taguchi, ANOVA, the voltage, feed rate , wire feed rate.*

I. INTRODUCTION

Wire EDM machining is an increasingly popular method globally known for its high precision capability and ability to machine complex shapes that are difficult to process by other methods. This technology is widely applied in various industries. However, the application of wire EDM not only brings benefits but also poses many challenges and issues that need to be addressed. Among them, the surface roughness of the product is an important factor directly affecting the assembly capability and working performance of the part. Therefore, analyzing the influence of certain technological parameters on surface roughness becomes essential.

Taguchi is an experimental optimization method proposed by Taguchi. Nowadays, the method is widely used

in industrial design. According to the Taguchi method, a series of experiments are conducted based on orthogonal arrays provided by Taguchi, based on the principle that the pair of states of the control factors in any two columns have equal probabilities of occurrence. With a set of cutting mode parameters in material processing, measuring some output

factors of interest such as tool wear, each factor of interest is repeatedly measured to ensure an accurate reflection of the influence of the technological factors on the output of interest. Some authors have used Taguchi analysis to determine the influence of cutting mode factors on the objective function, but the objective and constraint functions are constructed using traditional methods. Based on the analyses above, the paper aims to identify the main factors affecting surface roughness in the process of electrical discharge wire cutting. The paper is structured into 4 parts:
Part 1: Problem statement.
Part 2: Experimental setup for electrical discharge wire cutting processing.
Part 3: Results of analyzing the influence of some technological parameters on surface roughness during electrical discharge wire cutting processing.
Part 4: Main conclusions of the study are presented.

II. ESTABLISHING EXPERIMENT FOR MACHINING BY ELECTRICAL DISCHARGWIRE CUTTING METHOD

Picture 1. Wire cutting machine CHMER EDM CW 420 HS.

The process of electrical discharge machining wire cutting is carried out on the CHMER EDM CW 420 HS wire cutting machine with wire tension: 400 - 2500 gf, electrode wire diameter: 0.1 ÷ 0.3 (mm), machine table travel: XxYxZ = 400x280x220. Experiments are conducted with processing materials C45 steel (Ø14), SKD 11 steel (Ø16), S50C steel (Ø22). Surface roughness is measured using the Mitutoyo SJ-400 surface roughness tester.

Design of experiments Taguchi is a method commonly used in investigating the output parameters of a technological process obtained from the input parameters according to multiple factors and levels. This method has been successfully applied in various fields for the purpose of saving time, money, and obtaining optimal parameters.

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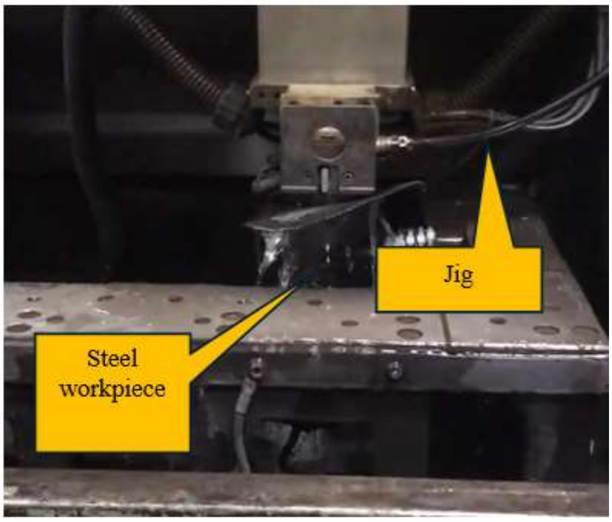


Picture 2. Perform cutting electric spark wire on steel blank.

The key to this approach is to create an orthogonal design table based on the factors and levels under investigation. The factors considered in the machining process include voltage, FR, and WF are described above.

TABLE 1. Experimental parameters when cutting electric spark wires.

Level	OV	FR	WF
1	70	1	3
2	75	2	4
3	80	3	5

The Taguchi method has selected the optimal solution based on analysis of variance (ANOVA) and signal-to-noise ratio (S/N ratio). The influence of factors on output parameters is evaluated through the S/N ratio. This index is determined by the formula:

$$\left(\frac{S}{N}\right) = 10\log\left[\frac{\overline{y_i}^{-2}}{s_i^2}\right] \quad (1)$$

In which:

$y_i = \frac{1}{N}\sum_{u=1}^{N_i} y_{i,u}$ is signal, $s_i^2 = \frac{1}{1-N}\sum_{u=1}^{N_i}(y_{i,u} - y_i)^2$ Signal-to-noise ratio, S/N, is the ratio of the signal power to the noise power. A large S/N ratio indicates a strong signal and low noise, especially when the output parameter is close to the optimal value. In the minimization problem (smaller is better), formula (1) is expressed as follows:

$$\left(\frac{S}{N}\right)_i = -10\log\left[\sum_{u=1}^{N_i}\frac{y_i^2}{N_i}\right] \quad (2)$$

In this study, the experimental design was established using the Taguchi L9 method, as presented in Table 2

TABLE 1. Experimental design using Taguchi method L9.

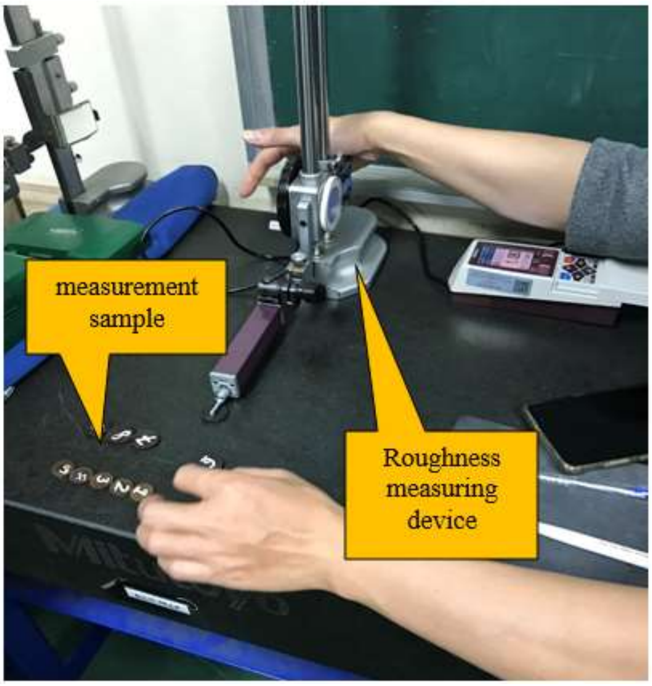
Ordinal number	The combination of factors and levels.		
	OV	FR	WF
1	70	1	1
2	70	2	2
3	70	3	3
4	75	1	2
5	75	2	3
6	75	3	1
7	80	1	3
8	80	2	1
9	80	3	2

In the minimization problem (the larger, the better), formula (2) is written as follows:

$$\left(\frac{S}{N}\right)_i = -10\log\left[\frac{1}{N}\sum_{u=1}^{N_i}\frac{1}{y_u^2}\right] \quad (3)$$

III. RESULT OF ANALYSIS OF THE INFLUENCE OF SOME TECHNOLOGICAL PARAMETERS ON SURFACE ROUGHNESS WHEN ELECTRICAL DISCHARGE WIRE CUTTING PROCESS

The Taguchi L9 experimental results shown in Table 3 indicate the surface roughness when cutting electric discharge wire of different materials. Tables 4, 5, and 6 present the comparison results of surface roughness under different machining conditions corresponding to the electric discharge wire cutting method. The results show that when cutting electric discharge wire, the surface roughness values vary under different cutting conditions. Comparing the roughness between samples, it is observed that under the same machining condition with different technological parameters, the surface roughness of SKD 11 material is the highest.



Picture 3. Measure surface roughness.

The results of measuring surface roughness are shown in Table 3:

TABLE 2. Surface roughness measurement results according to various technological parameters.

Surface roughness measurement table						
	Parameters			Material (micromet)		
	OV	FR	WF	C45	SKD11	S50C
1	70	1	3	1.044	0.994	1.551
2	70	2	4	1.376	1.067	1.431
3	70	3	5	1.122	3.098	1.529
4	75	1	4	1.51	1.261	1.156
5	75	2	5	1.042	1.054	1.08
6	75	3	3	0.752	0.989	0.955
7	80	1	5	1.309	2.467	1.941
8	80	2	3	0.976	0.692	0.715
9	80	3	4	1.269	2.264	1.333

The ANOVA analysis results on the surface roughness of the C45 steel material from the experimental wire cutting are shown in Table 4. The results indicate that the Output Voltage (OV) provides the highest S/N ratio (-1.19757) corresponding to level 2, followed by the Feed Rate (FR) with the highest S/N ratio (0.844462) corresponding to level 3, and finally the Wire Feedrate (WF) with the highest S/N ratio (0.60811) corresponding to level 1. ANOVA analysis is used to find the optimal solution for achieving the optimal roughness in the case of 231.

TABLE 3. Comparison table of the roughness of C45 steel.

Factor	Average S/N ratio		
	OV	FR	WF
1	-1.50469	-2.30849	0.60811
2	-1.19757	-1.17461	-2.86683
3	-1.53959	0.844462	-1.31205
Mean	-1.41395	-0.87955	-1.19026
Largest	-1.19757	0.844462	0.60811
Optimize	2	3	1

The ANOVA analysis results on the surface roughness of SKD11 steel material from the wire cutting experimental results are shown in Table 5. The results show that the Output Voltage (OV) provides the highest S/N ratio (-0.88627) corresponding to level 2, followed by the Feed Rate (FR) with the highest S/N ratio (0.412341) corresponding to level 2, and finally the Wire Feedrate (WF) with the highest S/N ratio (0.888387) corresponding to level 1. ANOVA analysis is used to find the optimal solution for achieving the smoothness corresponding to case 221.

TABLE 4. Comparison table of SKD11 steel roughness.

Factor	Average Signal-to-Noise Ratio		
	OV	FR	WF
1	-5.91959	-3.98643	0.888387
2	-0.88627	0.412341	-4.17987
3	-5.90717	-7.18818	-7.48049
Mean	-4.23768	-3.58742	-3.59066
Largest	-0.88627	0.412341	0.888387
Optimize	2	2	1

The ANOVA analysis results on the surface roughness of S50C steel material from the experimental wire cutting are shown in Table 6. The results indicate that the Output Voltage (OV) provides the highest S/N ratio (-0.56239) corresponding to level 2, followed by the Feed Rate (FR) with the highest S/N ratio (-0.9405) corresponding to level 2, and finally the Wire Feedrate (WF) with the highest S/N ratio (-1.05947) corresponding to level 1. ANOVA analysis was used to find the optimal solution for achieving the optimal roughness in the case of 221.

TABLE 5. Comparison table of S50C steel roughness.

Factor	Average S/N ratio		
	OV	FR	WF
1	-3.54825	-3.98485	-1.05947
2	-0.56239	-0.9405	-2.35611
3	-3.05036	-2.24166	-3.84516
Mean	-2.387	-2.38901	-2.42025
Largest	-0.56239	-0.9405	-1.05947
Optimize	2	2	1

IV. Conclusion

From the analysis of variance (ANOVA) results, conclusions are drawn regarding the influence of technological parameters on surface quality when cutting electric discharge wires for different materials C45, SKD11, S50C:

With C45 steel: the OV parameter provides the maximum S/N ratio (-1.19757) corresponding to level 2, next is the feed

rate (FR) with the maximum S/N ratio (0.844462) corresponding to level 3, and finally the wire feed rate (WF) with the maximum S/N ratio (0.60811) corresponding to level

In the case of SKD11 steel: the voltage (OV) provides the maximum signal-to-noise ratio (-0.88627) corresponding to level 2, next is the feed rate (FR) with the maximum signal-to-noise ratio (0.412341) corresponding to level 2, and finally the wire feed rate (WF) with the maximum signal-to-noise ratio (0.888387) corresponding to level 1.

For S50C steel: the voltage (OV) supplies the maximum S/N ratio (-0.56239) corresponding to level 2, next is the feed rate (FR) with the maximum S/N ratio (-0.9405) corresponding to level 2, and finally the wire feed speed (WF) with the maximum S/N ratio (-1.05947) corresponding to level 1.

References

[1] L.T.Hung, P.V.Bong, C.K.Trung, H.T.Dung, 2021. Applying taguchi method and fuzzy grey relationship analysis (fgra) to analyze the influence of cutting parameters on tool wear when high-speed milling of hardened steel.
[2] B.T.Long, N.H.Phan, N.Cuong, Vijaykumar S.Jatti, 2016. Optimization of PMEDM process parameter for maximizing material removal rate by Taguchi’smethod.
[3] N.H.Phan, T.Muthuramalingam, 2020. Multi Criteria Decision Making of Vibration Assisted EDM Process Parameters on Machining Silicon Steel Using Taguchi-DEAR Methodology.