International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (Volume 30, Special Issue of Nov 2018)
ISSN (Online): 2347-601X and Website: www.ijemhs.com

Optimization Of Wire Electric Discharge Machining OfComposite Material (Al6061/Sicp) Using Taguchi Method

Naga Sai Prasad [1*],Sai Gani Prasad [2]

[1*]Associate Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India

[2] Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India

*Corresponding author e-mail: nagasaiprasad@thenalanda.com

Abstract- When precision is crucial, wire electrical discharge machining (WEDM) is widely employed in industry to machine conductive materials. In this research, the Taguchi method is used to investigate and optimise WEDM parameters. Pulse on-time (Ton), Pulse off-time (Toff), and Discharge current were the three process parameters that were chosen (or pulse current). Using a L9 orthogonal array, the experiments were conducted in accordance with the design of experiments methodology. Surface Roughness (SR) signal to noise (S/N) ratios were computed for each experiment. Response graphs and analysis of variance (ANOVA) were used to analyse the data. According to the experimental findings, the ideal conditions—minimum surface roughness—were produced by pulse on-time of 5 s, pulse off-time of 3 s, and discharge current of 2 A.

Keywords*- Taguchi method; Optimization; WEDM; Surface roughness; Composite materiall*

I. INTRODUCTION

In comparison to non-reinforced alloys, Metal Matrix Composites (MMCs) are a new generation of engineered materials with improved physical and mechanical characteristics. In the automotive, aerospace, and defence industries, this makes them appealing for a wider range of applications. MMCs have extremely tough and abrasive reinforcing. As a result, they limit their ability to economically machine metal. It is extremely challenging to produce intricate shapes in such materials using conventional techniques. Unconventional material removal methods present an alluring alternative to traditional machining due to excessive tool wear and high tooling costs. WEDM is one of the numerous unorthodox techniques that has various industrial uses. Each work material must first undergo machining characterisation in order to develop high-quality, economically sound products.

Wire breakage was found to pose limitations on the cutting speed of MMC [4]. Open-gap voltage, Pulse-on period was the most significant influencing machining parameters, for controlling the MRR. Wire tension and wire feed rate are the most significant parameters influencing the surface roughness [5]. Due to presence of TiC particles and formation of Fe2O3 while machining results in the unstable machining process. NRBFN technique has several advantages like less complexity, requirements fewer training samples, easy input-output mapping, and less chance of getting local least convergence [6]. The material removal rate of wire electrochemical discharge machining of Al2O3 reinforced aluminium alloy 6061 was compared with WEDM machining of same material [7].

TAGUCHI METHOD

Taguchi method was developed by Dr. Genichi Taguchi. This method involves three stages: system design, parameter design, and tolerance design. In the Taguchi method, the experimental values are transformed into a signal-to-noise (S/N) ratio η. The term “signal” represents the desirable value (mean) for output characteristic and the term “noise” represents the undesirable value for the output characteristic. Usually there are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, nominal-the- better and the higher-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. The optimal level of the process parameters is the level having highest S/N ratio. Furthermore, ANOVA is performed to see which process parameters are statistically significant.
Smaller-is-better:

Nominal-is-better:

Larger Nominal-is-best:
Where, yij is the ith experiment at the jth test, n is the total test and s is the standard deviation.

The factor levels that have maximum S/N ratio are considered as optimal. The aim of this study was to produce minimum surface roughness (Ra) in WEDM machining operation. Smaller-the-better quality characteristic is used for surface roughness as smaller Ra values represent better or improved surface finish.

I. WEDM MACHINING EXPERIMENTS

Wire electrical discharge machining (WEDM), is a nontraditional machining method that is widely used to pattern tool steels for die manufacturing. In the WEDM process, a small wire is engaged as the tool electrode. The dielectric medium is usually de- mineralized (DM) water. The work piece is mounted on the table of the machine. The movement of the wire is controlled numerically to achieve the desired complex two and three-dimensional shapes for the work piece. WEDM uses electro-thermal mechanism to cut electrically conductive material. The material is removed by a series of discrete discharges between the wire electrode and the work piece in the presence of a dielectric fluid, which creates a path for each discharge as the fluid becomes ionized in the gap. The region in which discharge occurs is heated to extremely high temperatures, so that the work surface is melted and removed. The dielectric then flushes away the debris.

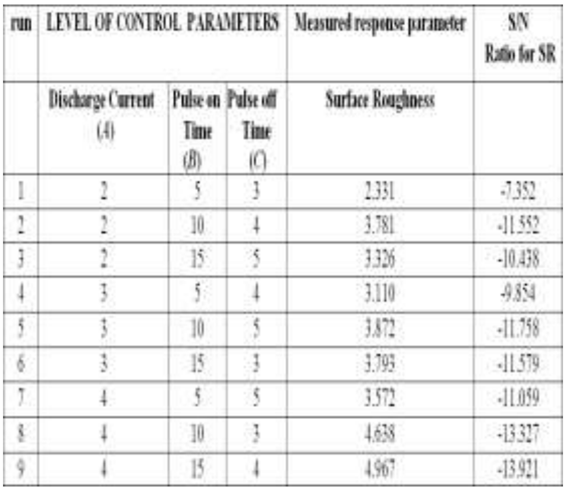
A. Selection of cutting parameters and their levels

In this study, a WEDM machine (DK-7712) was used to perform experiments. Aluminum alloy Al6061 was reinforced by hard Silicon carbide powder (10µm) SiC 10% in weight and this metal matrix composite material was synthesized by stir casting technique. Specimens were prepared that Based on the results of these analyses, optimal cutting parameters for minimum surface roughness are obtained and verified.

A. Analysis of the signal-to-noise (S/N) ratio

In this study, the lower-the-better performance characteristic is selected to obtain minimum surface roughness. The experimental results for surface roughness and the corresponding S/N ratio using equation (1) are shown in Table 2. TABLE 2

L_9 ORTHOGONAL ARRAY WITH THE VALUES OF RESPONSE VARIABLES



run	LEVEL OF CONTROL PARAMETERS			Measured response parameter	S/N Ratio for SR
	Discharge Current (A)	Pulse on Time (B)	Pulse off Time (C)	Surface Roughness	
1	2	5	3	2.331	-7.352
2	2	10	4	3.781	-11.552
3	2	15	5	3.326	-10.438
4	3	5	4	3.110	-9.854
5	3	10	5	3.872	-11.758
6	3	15	3	3.793	-11.579
7	4	5	5	3.572	-11.059
8	4	10	3	4.638	-13.327
9	4	15	4	4.967	-13.921

Since the experimental design is orthogonal, it is then possible to separate out the effect of each cutting parameter at different levels. The mean S/N ratio for each level of the cutting parameters is summarized and called the mean S/N response table for surface roughness (Table 3).

TABLE 3

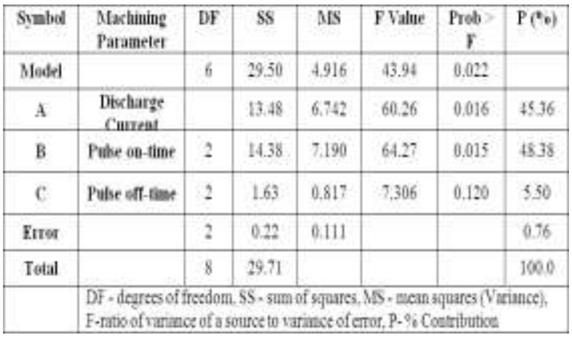
RESPONSE TABLE FOR AVERAGE S/N RATIO FOR SURFACE ROUGHNESS

	Control factors		
Levels	***A***	***B***	***C***
1	-9.78	-9.42	-10.75
2	-11.06	-12.21	-11.77
3	-12.77	-11.97	-11.08

Figures 2 show the mean S/N ratio graph for surface roughness. The S/N ratio corresponds to the smaller variance of the output characteristics around the desired value. From Table 3, the overall mean for the S/N ratio of SR found to be −11.20. Analysis of the result leads to the conclusion that factors at level A_1, B1, C_1, gives best SR.

TABLE 4

RESULTS OF THE ANOVA FOR SURFACE ROUGHNESS



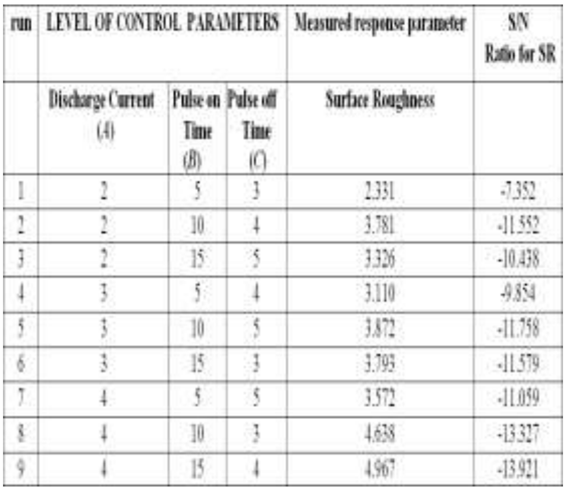
Symbol	Machining Parameter	DF	SS	MS	F Value	Prob > F	P (%)
Model		6	29.50	4.916	43.94	0.022	
A	Discharge Current		13.48	6.742	60.26	0.016	45.36
B	Pulse on-time	2	14.38	7.190	64.27	0.015	48.38
C	Pulse off-time	2	1.63	0.817	7.306	0.120	5.50
Error		2	0.22	0.111			0.76
Total		8	29.71				100.0
	DF - degrees of freedom, SS - sum of squares, MS - mean squares (Variance), F-ratio of variance of a source to variance of error, P- % Contribution						

B. Results and discussion

The Model F-value of 43.95 implies the model is significant. There is only a 2.24% chance that a "Model F-Value" this could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B is significant model terms.

Pulse on-time (T_{on}) with a contribution of 48.38% has the greatest effect on the machining output characteristics. Parameter A i.e. Discharge current with a 45.38% share is the next most significant influence on the output parameters, followed by Parameter C i.e. machine’s Pulse off-time, (T_{off}) 5.5%. Surface finish quality was better when applying smaller pulse time.

TABLE 2
L_9 ORTHOGONAL ARRAY WITH THE VALUES OF RESPONSE VARIABLES



run	LEVEL OF CONTROL PARAMETERS			Measured response parameter	S/N Ratio for SR
	Discharge Current (A)	Pulse on Time (B)	Pulse off Time (C)	Surface Roughness	
1	2	5	3	2.331	-7.352
2	2	10	4	3.781	-11.552
3	2	15	5	3.326	-10.438
4	3	5	4	3.110	-9.854
5	3	10	5	3.872	-11.758
6	3	15	3	3.793	-11.579
7	4	5	5	3.572	-11.059
8	4	10	3	4.638	-13.327
9	4	15	4	4.967	-13.921

Since the experimental design is orthogonal, it is then possible to separate out the effect of each cutting parameter at different levels. The mean S/N ratio for each level of the cutting parameters is summarized and called the mean S/N response table for surface roughness (Table 3).

TABLE 3
RESPONSE TABLE FOR AVERAGE S/N RATIO FOR SURFACE ROUGHNESS

	Control factors		
Levels	***A***	***B***	***C***
1	-9.78	-9.42	-10.75
2	-11.06	-12.21	-11.77
3	-12.77	-11.97	-11.08

Figures 2 show the mean S/N ratio graph for surface roughness. The S/N ratio corresponds to the smaller variance of the output characteristics around the desired value. From Table 3, the overall mean for the S/N ratio of SR found to be −11.20. Analysis of the result leads to the conclusion that factors at level A_1, B1, C_1, gives best SR.

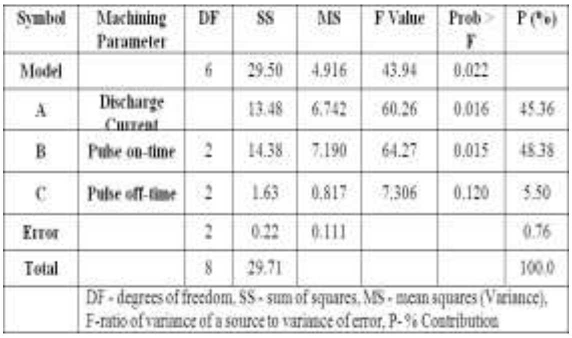
Figure 2: The smaller the better S/N graph for surfaceroughness.

This is because of small particle size and crater depths formed by electrical discharge. As a result, the best surface finish will be produced. The selection of these machining parameters for WEDM of any material should be used for a higher surface quality is required. It was observed that when

C. Analysis of variance (ANOVA)

The purpose of ANOVA was to investigate which machining parameters significantly affected the performance characteristics. This was accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean of the S/N ratio, into contributions by each of the process parameters and the error.

TABLE 4
RESULTS OF THE ANOVA FOR SURFACE ROUGHNESS



Symbol	Machining Parameter	DF	SS	MS	F Value	Prob > F	P (%)
Model		6	29.50	4.916	43.94	0.022	
A	Discharge Current		13.48	6.742	60.26	0.016	45.36
B	Pulse on-time	2	14.38	7.190	64.27	0.015	48.38
C	Pulse off-time	2	1.63	0.817	7.306	0.120	5.50
Error		2	0.22	0.111			0.76
Total		8	29.71				100.0
	DF - degrees of freedom, SS - sum of squares, MS - mean squares (Variance), F-ratio of variance of a source to variance of error, P- % Contribution						

D. Results and discussion

The Model F-value of 43.95 implies the model is significant. There is only a 2.24% chance that a "Model F-Value" this could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B is significant model terms. Pulse on-time (T_{on}) with a contribution of 48.38% has the greatest effect on the machining output characteristics. Parameter A i.e. Discharge current with a 45.38% share is the next most significant influence on the output parameters, followed by Parameter C i.e. machine’s Pulse off-time, (T_{off}) 5.5%. Surface finish quality was better when applying smaller pulse time. This is because of small particle size and crater depths formed by electrical discharge. As a result, the best surface finish will be produced. The selection of these machining parameters for WEDM of any material should be used for a higher surface quality is required. It was observed that when Discharge current and particularly pulse on time increased, machined work piece surface exhibited a higher surface roughness due to irregular topography. Discharge current had an effect on surface roughness at low pulse time, but the influence of pulse on- time was more significant than Discharge current at higher pulse times. It was noticed that high Discharge current and pulse times will produce a poor surface finish due to deeper and wider crates on the machined surface. Excellent machined surface quality could be obtained by setting machining parameters at a low short pulse on- time.

CONCLUSIONS

To determine the impact of different WEDM process parameters on surface roughness, a series of tests were conducted. ANOVA is used to assess the relative importance of the machining parameters and each one's individual impact on the surface roughness. These outcomes were attained:

- • With a contribution of 48.38%, pulse on-time (Ton) has the biggest impact on the machining output characteristics. The second most important factor affecting the output parameters is Parameter A, or discharge current, with a 45.38% share, followed by Parameter C, or machine pulse off-time (Toff), at 5.5%.
- Surface roughness at the best combination is 2.331 µm.
- The following factor-level settings have been identified to yield the best combination;

Input parameter A – Level 1, (Discharge Current - 2A) Input parameter B – Level 1, (Pulse on-time - 5µs)

Input parameter C – Level 1, (Pulse off-time - 3µs)

REFERENCES

[1] Rozenek M., Kozak J., Dalbrowski L., Eubkowski K., “Electrical discharge machining characteristics of metal matrix composites,” J Mater Process Technol 109:367–370, 2001

[2] Guo Z.N., Wang X., Huang Z.G., Yue T.M., “Experimental investigation into shaping particles-reinforce material by WEDM,” J Mater Process Technol 129:56–59, 2002

[3] Yan, B.H, Tsai H.C., Huang F.Y., Lee L.C., “Examination of wire electrical discharge machining of Al_2O_3p/6061Al composites,” Int J Mach Tools Manuf 45:251–259, 2005

[4] Patil N.G., Brahmankar P.K., “Some investigations into wire electro-discharge machining performance of Al/SiCp composites,” Int J Machin Machin Mater 1(4):412–431, 2006

[5] Manna A., Bhattacharyya B., “Taguchi and Gauss elimination method: A dual response approach for parametric optimization of CNC wire cut EDM of PR Al SiC MMC,”. Int J Adv Manu Tech 28:67–75, 2006

[6] Probir S., Debashis T., Pal Surjya K, Partha S, Srivastava Ashok K, Karabi D., “Modeling of wire electro-discharge machining of TiC/Fe in situ metal matrix composite using normalized RBFN with enhanced k-means clustering technique,” Int J Adv Manuf Technol 43:107–116, 2009

[7] Liu, J.W., Yue T.M., Guo Z.N., “Wire electrochemical discharge machining of Al2O3 particle reinforced aluminum alloy 6061”. Mater Manuf Process 24:446–453, 2009