Parametric Optimization

Prof. Naimesh Kadiya
Narayan shastri institute of technology, jetalpur
university:Gujarat Technological university

Abstract-
This research used a stir-casting technique to create a Metal Matrix Composite (MMC) made of Al7075 and Al2O3 under Parametric Optimization. Wire Electrical Discharge Machining (WEDM), the outcome responses in term of Surface Roughness (Ra) and Material Removal Rate (MRR) were examined as a function of five parameters areCurrent, Pulse ON, Voltage, Pulse OFF, and Bed Speed. Taguchi's L18 orthogonal array has been utilized for experimentation. Analysis of the Signal-to-Noise Ratio (S/N) was used to evaluate the responses from the output, and Analysis of Variance (ANOVA) was used to find the parameters with the most significant effect. The experimental results were used to identify the optimal values of parameters that optimize to reduce the Surface Roughness (Ra) and Material Removal Rate (MRR).

Keywords - MRR, WEDM, MMC, Ra, Minitab 17 software, Taguchi orthogonal array.
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I. Introduction

In mathematical programming and parametric optimization, the behaviors and features of optimal solutions to optimization problems are analyzed as they change in response to modifications in the descriptive data (parameters). Parameter-dependent optimization issues always emerge when creating a model for a wide range of real-world problems. The research of parametric optimization also has strong connections to many other optimization theories and applications, such as duality and approximate solution theory, multi-objective optimization, stochastic optimization, semi-infinite optimization, optimal control, ill-posed difficulties, and numerical solution methods. In the past two decades, parametric optimization has experienced rapid and volatile expansion [2]. Initiated and directed by Prof. F. Nozicka, the 'Parametric Optimization' research group at the Mathematics Department of Humboldt-University Berlin was established in the early 1970s. Each research paper in this special issue has at least one author member of this research group. As such, they all share a common interest in the theory and applications of parametric optimization. There are primary categories for composites are Ceramic Matrix Composites (CMC) and Metal Matrix Composites (MMC) is both examples of reinforcement used in the creation of Polymer Matrix Composites (PMC). Composite's benefits include its low weight, high strength, resistance to corrosion and impact, and dimensional stability. The exceptional combination qualities of the Aluminum Matrix Composite (AMC) include higher hardness, high strength, and thermal and electric conductivities. All-Metal Components (AMCs) have several applications in the aerospace, automotive, and defense industries.

In Figure 1, a wire is employed as a cutting tool during the EDM process of material removal. Dielectric fluid is continually flushed to the working zone to shred the material of the work piece and flush the eroded particles while simultaneously acting as a coolant [1]. By using a Taguchi orthogonal arrayand can do fewer experiments while maintaining or improving the same precision level.The S/N Ratio is utilized as a proxy for the experimental results, and Analysis of Variance (ANOVA) is perform to evaluate each element's relative influence and optimal value on the output response.

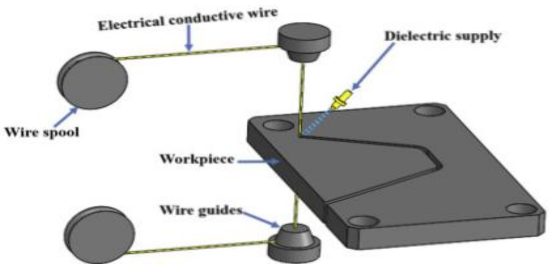

Figure 1 Schematic Diagram for WEDM (Source: [9])

Aim

The matrix material is the main focus of Parametric Optimization, whereas the reinforcing material is obtained better. Al 7075 and Al 2O3 Metal Matrix Composite were machined using Wire Electrical Discharge Machining, and the output response in terms of Surface Roughness and Material Removal Rate were analyzed as a function of five parameters: Voltage, Bed Speed, Pulse OFF, Pulse ON, and Current.

Objectives

The objectives are

- To determine the best setting for each variable and the weight they carry in the outcome.
- To generate better results from fewer Taguchi Orthogonal Array experiments.
- To find out which variables impact the most in Analysis of Variance (ANOVA).

Research Question

Maximizing Material Removal Rate while keeping Surface Roughness to a minimum presents a challenge; how best to solve this problem?

II. Literature Review

Wire EDMs can erode the work piece into complex 2D and 3D shapes following a Numerically Controlled (NC) route using de ionized water as dielectric medium and a thin wire electrode. According to [3], improved stability and increased efficiency in the WEDM processes are two of the main goal of both WEDM consumers and manufacturers.

Consumers and manufacturers of wire electrical discharge machining, like those described by [4], emphasize achieving increased machining productivity while retaining the product's quality in terms of accuracy and surface quality. Even with a state-of-the-art WEDM and a highly competent operator, achieving peak performance is challenging because of the enormous number of factors at effect. Discovering the connection between process performance metrics and their corresponding modifiable inputs is a practical approach to resolving this issue.

The effects of machining the input parameter on WEDM performance have been investigated and reported on by [5].Single sparks of SiC/Al work materials were researched by [6], who looked at how spark on time affected the size of the resulting impacts.[7] Employed a factorial design method to find the best possible WEDM control settings regarding metal removal rate and surface quality. Findings suggest that pulse duration, discharge current, and pulse frequency are all significant regulators.To predict the surface finish, [8] implemented a neural network model with input settings including open circuit voltage, electric capacitance, pulse interval, peak current, servo orientation voltage, pulse duration, and table speed.

III. Methodology

Data Collection

Matrix Material Aluminum Al7075 Alloy was chosen because its mechanical properties, including fatigue strength, and machinability, corrosion resistance, exceed those of any other type of Aluminum alloy. Table 1 shows the chemical compositions of Al7075.

Table 1 Chemical composition of Al7075

Content	Al	Zn	Ti	Mg	Mn	Cr	Cu	Si	Fe
Compositions (%)	Bal	6	0.3	3	0.4	0.3	2	0.5	0.6

Particles of Al 2O3 (Alumina) with a size between 50 and 100 microns were employed as reinforcement in a 90%-10% ratio. Alumina is a popular material in the engineering ceramic family due to its low price and high quality combination of features. Alumina's small granularity allows it to be used in many different settings. Table 2 displays the chemical components of Al203.

Content	AL2O3	Si O2	Na2O	Fe 2 O3	Ti O2
Compositions (	Bal	0.15	0.45	0.05	0.15

Table 2 Chemical composition of Al 2O3

Data Preparation

Aluminum Al7075 was used as the primary matrix in the preparation, with Al2O3 particles ranging in size from 50 to 100 microns added as reinforcement at a weight-to-weight ratio of 90%. Aluminum Al7075 alloys was melted for 30 minutes at 7400 C in a 6kw melting furnace heated by silicon elements. After 15 minutes of being agitated at 300 rpm by a ceramic-coated metal stirrer, the mixture was put into a warmed steel mold.

WEDM

Wire Electrical Discharge Machining (WEDM) is used. Experiments were run on a DK-7732 WEDM machine tool, with input parameters chosen according to the manufacturer's recommended ranges for various thicknesses and materials. For this research, to employ a 0.18mm-diameter molybdenum wire and a dielectric fluid made of dematerialized water with JR3A gel. The selection of processing parameters was based on machine capability. The experiments in Table 3 were conducted using the Pulse off, Pulse on; Voltage, Current, and the Bed Speed parameters are specified.

Table 3 Machining Parameters used in experiments

Parameter		Levels			
		I	II	III	Units
A	Bed Speed	50	150	250	
B	Pulse on	30	20	40	μ
C	Pulse off	12	15	9	μ
D	Voltage	75	100	0	Volts
E	Current	2	4	6	Amps

Material Removal Rate can be calculated with

$$MRR = \frac{(2 \times Wg + D) \times t \times L}{T}$$

Where T = time taken to incise "min."

L = Distance Travelled by Tool – "60 mm"

t = Thickness of Work Piece – "10 mm"

D = Diameter of Wire – "0.18 mm"
Wg = Spark Gap – "0.02 mm

Data Design

Taguchi technique, invented by Dr. Genichi Taguchi, is based on the Design of an Experiment (DOE). The DOE method, developed by R.A. Fisher, allows researchers to examine many factors simultaneously. The orthogonal array (OA) table, derived from the DOE method, is to minimize the total number of experiments. According to Table 4, the researcher decided to perform the experiment using the L18 (23) orthogonal array.

Table 4orthogonal array

Parameter		Levels			
		I	II	III	Units
A	Bed Speed	50	150	250	$\frac{\mu m}{sec}$
B	Pulse on	30	20	40	μsec
C	Pulse off	12	15	9	μsec
D	Voltage	75	100	0	Volts
E	Current	2	4	6	Amps

The experiments were analyzed using S/N and ANOVA to determine the most significant parameter values and the relative parameters influences on the outcomes i.e. (Ra, MRR).For S/N ratio, "Larger is better," "Nominal is better," and "Smaller is better" describe more and less favorableoutcomes progressively. Using a logarithmic transformation function, and the S/N ratio for Ra and MRR Equation (1). S/N ratios with a larger "size are better" and smaller "size is better" Equation (2) values are shown in Table 5.

$MRR = -10 \, log \, (\sum (\frac{1}{y^2})/n)$ ------- Equation 1

$RA = -10 \, log \, (\sum \frac{y^2}{n})$ ----------Equation 2

IV. Findings and Discussion

Minitab-17 was used for the statistical analyses of the experiments' outcomes. The MRR and Ra measurements' signal-to-noise ratios were converted for the Al 7075 and the Al 2O3 metal matrix composites. L 18 (2 * 3) under orthogonal array is modified in Table 5.

Table 5 L 18 (2 * 3) Orthogonal Array

L 18 (2* 3) OA				
Experiment Number	MRR	MRR- S/N ratio	Ra	Ra - S/N ratio
	mm/min	dB	μm	dB
1	30.137	29.582	1.405	-2954
2	5.641	15.027	1.784	-5.028
3	17.671	24.945	1.739	-4.806
4	17.984	25.098	1.572	-3.929
5	5.911	15.434	1.576	-3.951
6	5.877	15.383	1.501	-3.528
7	17.483	24.853	1.595	-4.055
8	11.681	21.350	1.768	-4.950
9	14.270	23.089	1.729	-4.756
10	28.884	29.213	1.759	-4.905

Signal Noise (S/N) ratio

Figure 2 displays a scatter plot of the signal to noise ratio (S/N) for the MRR. In the graph, the optimum value obtained is Current 6 Amp, PulseON 40(µs), Voltage 100 volts, PulseOFF 9(µs), Bedspeed 250 (µm/s). Maximum MRR is achieved at this value. Fig. 3 is a scatter plot of the Signal-to-Noise Ratio versus Surface Roughness. The best parameters, as determined by the graph, are Current of 6 Amp, Voltage of 100 volts, Pulse-OFF 15 (µs), Pulse-ON 40 (µs), and Bed speed of 50 (µm/s). Minimum Ra

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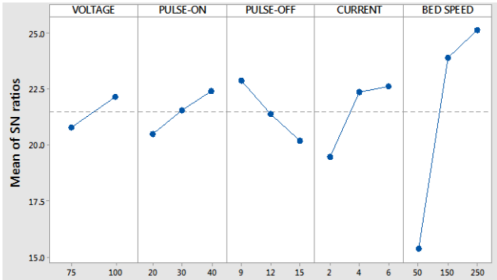

is achieved at this value.

Figure 2 Signalto Noise (S/N) Ratio - Larger is Better "MRR"

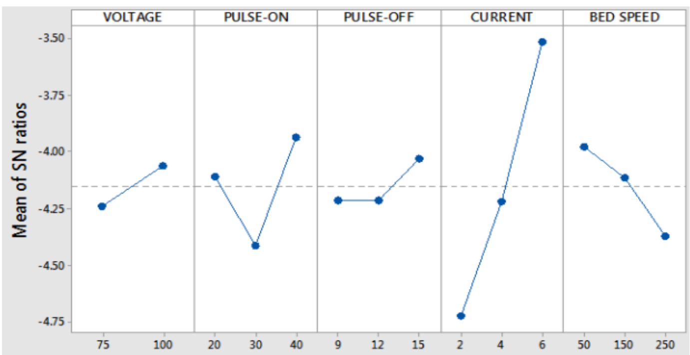

Figure 3 Signal to Noise (S/N) Ratio - Smaller is Better "Ra"

A table 6 and 7 displays the S/N ratio for Material Removal Rate and Surface Roughness.

Table 6 Taguchi Analysis: Current, Pulse ON, Pulse OFF, MRR v/s Voltage, Bed Speed.

L 18 (2 * 3) orthogonal array					
Experiment	voltage	pulse on	pulse off	current	bed speed
Number	volt	microsecond	microsecond	amp	microsecond per second
1	75	40	12	4	150
2	100	40	9	2	50
3	75	30	12	6	50
4	100	20	9	6	150
5	75	20	12	6	150
6	100	40	15	4	150
7	100	40	12	2	50
8	75	30	15	6	50
9	100	20	15	4	50
10	75	40	15	6	250

Table 7 Taguchi Analysis: Ra v/s Voltage, Current, Pulse-ON, Pulse-OFF, Bed Speed.

r Signal to noise ratios "Smaller is Better"					
Levels1	voltage	Pulse on	Pulse off	current	bed speed
01	-04.24025	-04.10715	-04.21412	-04.72332	-03.97472
02	- 04.06120	- 04.41220	- 04.21250	- 04.21752	- 04.11023
03	----	- 03.93359	- 04.02626	- 03.51263	- 04.36885
Delta	.18002	.47975	.18715	.21021	.39332
Grade	5.0	2.0	4.0	1.0	3.0

Analysis of Variance (ANOVA)

Tables 8 and 9 show the analysis variance results for Surface Roughness and Material Removal Rate.

Table 8 Regression Analysis: MRR v/s voltage, Current, Pulse OFF, Pulse ON, and Bed Speed.

Analysis of variance					
Sources	DF	Adj SS	Adj MS	F value	P value
Regression	05	810.682	72.145	146.018	.00
Pulse ON	01	44.31	44.31	4.13	.065
Pulse OFF	01	99.69	99.69	9.28	.010
Voltage	01	42.95	42.95	3.99	.069
Current	01	114.764	104.762	7.745	.08
Bed speed	01	518.972	58.971	12.986	.00
Error	13	29.012	12.752	----	----
Overall	18	989.80	----	---	---

Table 9 Regression Analysis: Ra v/s Voltage, Current, Pulse-ON, Pulse-OFF, Bed Speed

Analysis of variance					
Sources	DF	Adj SS	Adj MS	F value	P value
Regression	05	.177	.035	04.052	.02
Pulse ON	01	.002	.002	.34	.57
Pulse OFF	01	.003	.003	.44	.51
Voltage	01	.005	.005	.57	.46
Current	01	.148	.148	15.034	.01
Bed speed	01	.016	.016	12.872	.1962
Inaccuracy	13	.104	.008	---	---
Overall	18	.280	----	---	---

V. Conclusion

The stir casting procedure successfully created a metal matrix composite (MMC) of Al 7075 and Al 2O3, and the experiment was conducted using a Taguchi L18 Orthogonal Array. The S/N Ratio and the ANOVA test results indicated that the MRRR and Ra might be further improved by employing the Taguchi method. The material removal rate is primarily sensitive to a single variable bed speed. There is less impact from the Voltage, Pulse OFF, Pulse ON, and Current. The proposed amounts of factors employed in this work indicate that the optimal grouping of parameters underVoltage 100volts, Pulse on 40 microseconds, Pulse Off 9 microseconds, Current6 amperes, and Bed speed250 micrometers per second. In this case, the current is the most critical factor in determining the Surface roughness. The Pulse ON, Pulse OFF, and Bed speed, as well as the Voltage, have much less of an impact. Maximum surface roughness may be achieved with the following parameters are Voltage 100volts, Pulse on 40 microseconds, Pulse off 9microseconds, Current 6 amperes, and Bed speed 250micrometers per second.

VI. Reference

[1] S. Pattnaik and M. Sutar, "Advanced Taguchi-Neural Network Prediction Model for Wire Electrical Discharge Machining Process", Process Integration and Optimization for Sustainability, vol. 5, no. 1, pp. 159-172, 2021. Available: 10.1007/s41660-020-00148-1.

[2] MantiumCAE, "Parametric Optimization - MantiumCAE", MantiumCAE, 2022. [Online]. Available: https://mantiumcae.com/mantium/parametric-optimization/. [Accessed: 11- Oct- 2022].

[3] L. Straka, J. Pitel and P. Michalik, "Research of Geometric Accuracy of Circular Holes Machined by Wire EDM Technology", Tehnickivjesnik - Technical Gazette, vol. 28, no. 5, 2021. Available: 10.17559/tv-20200925142859.

[4] P. Sivaprakasam and P. Hariharan, "Surface characteristics of nano powder mixed micro-wire electrical discharge machining on inconel alloy", Materials Today: Proceedings, vol. 38, pp. 494-498, 2021. Available: 10.1016/j.matpr.2020.02.329.

[5] Q. Liu, F. Yang, S. Sun, M. Yang and J. Shao, "Surface Integrity of Micro EDM Surface Using Electrodes of Various Diameters", Coatings, vol. 9, no. 12, p. 805, 2019. Available: 10.3390/coatings9120805.

[6] Q. Liu, F. Yang, S. Sun, M. Yang and J. Shao, "Surface Integrity of Micro EDM Surface Using Electrodes of Various Diameters", Coatings, vol. 9, no. 12, p. 805, 2019. Available: 10.3390/coatings9120805.

[7] A. Sagbas, "Analysis and Optimization of Process Parameters in Wire Electrical Discharge Machining Based on RSM: A Case Study", Response Surface Methodology - Research Advances and Applications [Working Title], 2022. Available: 10.5772/intechopen.107539 [Accessed 11 October 2022].

[8] A. Polishetty and G. Littlefair, "Evaluating Optimal Parameters for Machining Selective Laser Melting Titanium Alloy Using Wire Cut Electrical Discharge Machining", International Journal of Manufacturing, Materials, and Mechanical Engineering, vol. 10, no. 3, pp. 62-72s, 2020. Available: 10.4018/ijmmme.2020070104.

[9] AmitRai Dixit, 2022. [Online]. Available: https://www.researchgate.net/figure/Schematic-diagram-of-WEDM-setup_fig1_264837095. [Accessed: 11- Oct- 2022].