

Research Article

ANALYSIS OF WEDM PARAMETERS IN MACHINING OF AL6061 COMPOSITE ALLOY USING DESIGN OF EXPERIMENTS

T. Mythili^{1*}, R. Thanigaivelan², R. Gurumani³, T. Mothilal⁴

¹Mahendra Engineering College, Mallasamudram, Tamil Nadu, India

²Shreenivasa Engineering College, Dharmapuri, Tamil Nadu, India

³VELS Institute of Science, Technology & Advanced Studies, Chennai, Tamil Nadu, India

⁴Department of Mechanical Engineering, Faculty of Engineering and Technology, SRM Institute of Science and Technology Ramapuram, Chennai, Tamil Nadu, India

Abstract

Aluminium metal matrix composites are finding irreplaceable place in the aircraft and vehicle for its weight to strength ratio. The advent of new materials is really posing challenges on machinability characteristics especially in conventional machining. The metal matrix composites material during machining often experience the overcut, formation of sharp edges and excessive tool wear. To overcome the machining challenges, aluminium metal matrix composite (AMMC) i.e. Al6061 alloy reinforced with 6% wt of Al_2O_3 is machined using Wire Electric Discharge machine (WEDM). The chosen experimental design was implemented to investigate the impact of process parameters on the output parameters e.g. machining rate and surface roughness (R_a). The chosen process variables were varied up to five levels and central composite design (CCD) was adapted to Design of Experiments (DoE). To create a second order regression equation connecting response characteristics and process variables, response surface methodology (RSM) was applied. R^2 values of MR and R_a are found to be 90.36% and 91.05%, respectively. Based on ANOVA, the most influencing parameter that affects the MR is found to be peak current (B) which is at 74.20%. Moreover, the most influencing parameter that affects the R_a is found to be peak current (B) which is at 62.04%. The error percentage is notably low at 0.44% and 0.84% for MR and SR, respectively.

Keywords: Composites, WEDM, Machining rate, Surface roughness, ANOVA, Regression equation.

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***Corresponding author:** T. Mythili
Email: tvelan10@gmail.com

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1. INTRODUCTION

Utilising a thin wire as an electrode, the Wire Electric Discharge Machining (WEDM) technique transforms electrical energy into heat energy for material cutting. Alloy steel, conductive ceramics, and aerospace materials can be machined with this method regardless of their hardness and toughness. Furthermore, WEDM is capable of producing a precise, fine, corrosion- and wear-resistant surface. There is a steady development of new materials with ever-increasing strengths and capacities, and the materials of the work component influence the output characteristics in addition to the machining parameters (Ho et al., 2004). Using WEDM, researchers have studied the machinability of AMMCs. The data was then analysed using optimisation techniques on output attribute such material removal rate (MRR), surface

roughness (R_a), and surface topography. The impact of process parameters and their optimization—which is crucial for the WEDM technology's commercialization—are covered in the preserved literatures. Using a wire-cut electric discharge machining procedure, Kumar et al. (2018) discussed the machining aspects of particulate silicon carbide reinforced Al/SiCp-MMC. For efficient machining of Al/SiCp-MMC, the study suggests the following process parameters: wire tension of 1200 g; wire feed rate of 10 m/min; pulse on time of 0.75 μ s; spark gap voltage of 35 V; pulse off time of 16 μ s; peak current of 120 A. These parameters are also confirmed through confirmation experiments. Maurya et al. 2024 have conducted WEDM on hybrid Al/(SiC+ ZrO₂+ NiTi)-MMC and optimised the

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WEDM parameters on MRR and R_a . From the results of analysis of variance (ANOVA), gap voltage and pulse-on-time were established as significant factors for MRR and SR. Gore et al. (2024) have formulated a mathematical model for WEDM process for machining of Al/SiC/p to predict crater size and MRR. Model forecast good relationship among the variables with experimental and computer-generated results for Al/SiC/10% with 2% error. Vinoth et al 2023 stir casted an AA6070 metal matrix composite with 5% and 10% MgO weight fraction (wt) and machined using WEDM. L_{18} mixed Orthogonal Array (OA) studies can be used to test and evaluate R_a and MR. Based on TOPSIS analysis, the following processing factor combinations have been found to improve MR and R_a : wt = 5%, vg = 50 V, WT = 13 g, Ip = 9 A, and Pd = 15 bar. Patil 2023 has WEDMed Al/Al₂O₃/22p and developed empirical models to predict the cutting speed, surface roughness and kerf width. It was identified that the cutting speed and surface finish were highly influenced by the pulse on-time. Further wire speed, wire tension, pulse on-time, and off-time all had an impact on kerf breadth. Sudhagar et al. (2024) have reported how a magnesium hybrid composite's machinability is affected by Si₃N₄-BN hybrid reinforcement in WEDM. The shared ideal process parameters for each of the three output responses under consideration were found using grey relational analysis (GRA). The following input settings were determined as producing the highest cutting speed, minimal R_a , and Kerf width: 0% Si₃N₄ and BN, 6 s pulse on time, 14 s pulse off time, 6 m/min wire feed speed, and 10 g wire tension. Senthil Kumar et al. (2023) investigated the tribological property using the response surface methodology technique. It's also used in the WEDM process to forecast overcut, surface roughness, and material removal rate. The perturbation figure indicates that the projected values for the wear and WEDM parameters are well within the minimal error value, and adequate validation has been carried out. Better tribology and WEDM features are obtained at 15 N, 2 m/s, 750 m, and 15 A, 90 μ s, and 45 V, according to the developed model. Prakash et al. 2023 presents an effective method for improving WEDM machining settings of AMMCs with different performance characteristics, based on GRA. The matrix material and B₄C of 3%, 6%, and 9% by weight as reinforcement, stir casting was utilised to create AMCs (413/B₄Cp). In this study, input parameter optimisation takes into consideration the performance attributes of SR and MRR. The expected value of the GRG is 0.784, however the experimented value is 0.772. Gotagunaki et al 2023 investigated the effects of machining parameters, such as pulse on, pulse off, and peak current, on response variables, such as electrode wear, surface roughness, and material removal rate, in the context of WEDM machining of AZ91D Mg hybrid metal matrix composite reinforced with rare earth oxides (Y₂O₃ and CeO₂). The multi-objective optimisation of replies based on the grey relational grade analysis was carried out using the Taguchi coupled GRA. The best possible combination of WEDM machining settings was achieved

with a pulse on time of 40 μ s, a pulse off time of 20 μ s, and a peak current of 2A for the rare earth oxides reinforced AZ91D Mg hybrid composite. Dhillip et al 2023 WEDMed a hybrid composite consisting of an AMMC reinforced with both molybdenum disulphide (MoS₂) and boron nitride. An entropy approach weight in conjunction with the visekriterijumska optimizacija kompromisno resenjeje (VIKOR) method was used to identify the optimal settings. The entropy weight criteria in this work were 0.52 for R_a and 0.48 for MRR. The VIKOR evaluation yielded the best ideal parameters: Tonne of 8 μ s, Toff of 28 μ s, WF of 7 m/min, WT of 12 g.

Therefore, as per the above discussion the machining of AMMC with WEDM is performed and still there is a lack of knowledge in WEDM machining characteristics on Al6061 alloy reinforced with 6% wt of Al₂O₃. Hence in this research CCD experimental plan were used and RSM based mathematical was developed. The effect of WEDM parameters on MR and R_a was identified using the ANOVA and the interaction plot analyse the relation between WEDM factors and performance.

2. EXPERIMENTAL SETUP

Figure 1 shows the Mitsubishi make WEDM, which is considered for the machining of AMMC (Al6061 alloy reinforced with 6% wt of Al₂O₃). The brass wire of diameter of 0.25mm and distilled water is used as a dielectric. The input variables such as, gap voltage, input current, wire tension and dielectric pressure at different levels were varied on MR and R_a . Mitutoyo, model Surf test SJ-210 is used for measuring R_a . Table 1 presents the parameters and code levels.



Figure 1: WEDM setup

3. RESPONSE SURFACE METHODOLOGY (RSM)

When analysing problems where numerous independent factors affect a dependent variable, response optimisation is the goal of response stochastic modelling (RSM), a combination of statistical and mathematical tools (Kumar, 2014). RSM has proven helpful in the current work by helping to create the multiple regression equations that represent the quality characteristic in the WEDM process. The dependent variable is seen as a surface to which a

mathematical model is fitted when using the RSM. The second order response surface has been assumed as shown in the equation 2 for the development of regression equations related to various quality characteristics of WEDM process.

$$Y = b_0 + \sum_{i=1}^k b_i x_i + \sum_{i=1}^k b_{ii} x_i^2 + \sum_{i < j=2}^2 b_{ij} x_i x_j \pm e_i \quad (1)$$

This formula includes terms for variables that are linear, squared, and cross-product. The CCD method suits the second order response surfaces quite well, according to Box and Hunter's 1957 proposal.

3.1. CENTRAL COMPOSITE DESIGN (CCD)

At any location that is equally spaced from the region's centre in a CCD architecture, the standard error stays constant. Let's say that the region where the relationship between Y and X is being studied has its centre at (0, 0, ---, 0). Y's standard error, or e_i , can be calculated at any point on the fitted surface using the experiment results. The point's coordinates, x_i , determine how this standard error functions. The standard error remains the same at all equidistant places with a distance of ρ from the region's centre due to the rotatability

requirement, meaning that it applies to all points that fulfil the attached equation:

$$x_1^2 + x_2^2 + \dots + x_k^2 = \rho^2 = \text{constant} \quad (2)$$

4. RESULTS AND DISCUSSION

WEDM experiments conducted using the process parameter levels specified in Table 1. To investigate the impact of process parameters on output performance, the CCD's test conditions were followed for conducting the experiments (Table 2). Table 2 displays the results of the experiments for surface roughness (Ra) and machining rate (MR). In total 30 experiments were conducted using RSM (Venugopal et al. 2023).

Table 1: Parameters and coded levels

Parameters	Coded factors	-2	-1	0	1	2
V _g	A	51	53	55	57	59
IP	B	2	4	6	8	10
WT	C	8	9	10	11	12
P _d	D	10	11	12	13	14

Table 2: RSM table and results

Std. order	Run order	A	B	C	D	Vg	IP	WT	Pd	MR mm/min	Ra μm
1	8	-1	-1	-1	-1	53	4	9	11	0.90	3.298
2	15	+1	-1	-1	-1	57	4	9	11	0.91	3.478
3	20	-1	+1	-1	-1	53	8	9	11	1.13	3.563
4	18	+1	+1	-1	-1	57	8	9	11	1.26	3.542
5	9	-1	-1	+1	-1	53	4	11	11	0.88	3.234
6	2	+1	-1	+1	-1	57	4	11	11	1.07	3.345
7	10	-1	+1	+1	-1	53	8	11	11	1.39	3.757
8	30	+1	+1	+1	-1	57	8	11	11	1.44	3.820
9	11	-1	-1	-1	+1	53	4	9	13	0.86	3.511
10	28	+1	-1	-1	+1	57	4	9	13	0.89	3.671
11	26	-1	+1	-1	+1	53	8	9	13	1.11	3.822
12	14	+1	+1	-1	+1	57	8	9	13	1.20	3.781
13	27	-1	-1	+1	+1	53	4	11	13	1.01	3.423
14	17	+1	-1	+1	+1	57	4	11	13	1.08	3.521
15	23	-1	+1	+1	+1	53	8	11	13	1.29	3.654
16	29	+1	+1	+1	+3	57	8	11	13	1.38	3.721
17	19	-2	0	0	0	51	6	10	12	1.16	3.547
18	12	+2	0	0	0	59	6	10	12	1.29	3.599
19	7	0	-2	0	0	55	2	10	12	0.73	3.372
20	13	0	+2	0	0	55	10	10	12	1.56	3.981
21	24	0	0	-2	0	55	6	8	12	1.26	3.598
22	3	0	0	+2	0	55	6	12	12	1.33	3.661
23	1	0	0	0	-2	55	6	10	10	1.14	3.546
24	25	0	0	0	+2	55	6	10	14	1.17	3.677
25	5	0	0	0	0	55	6	10	12	1.18	3.695
26	4	0	0	0	0	55	6	10	12	1.12	3.689
27	21	0	0	0	0	55	6	10	12	1.18	3.673
28	22	0	0	0	0	55	6	10	12	1.11	3.595
29	16	0	0	0	0	55	6	10	12	1.13	3.655
30	6	0	0	0	0	55	6	10	12	1.14	3.667

4.1. REGRESSION ANALYSIS

The development of approximating model is concerned with regression analysis. It is a very useful and commonly used method for data analysis. This leads to simple, yet often effective explanations of the main characteristics of the different variable's relationships. Blair (2019) defines

regression as the average association between two or more variables expressed in terms of the original units of the results. This analysis gives a relationship between parameters which are independent and dependent in nature. Here, the dependent parameters are MR and R_a , whereas the independent parameters are voltage gap (Vg), peak current (IP), wire tension (WT) and dielectric pressure (Pd).

Table 3: Predicted MR and R_a based on regression equations

Experimental No.	Actual MR (mm/min)	Predicted MR (mm/min)	Actual $R_a(\mu\text{m})$	Predicted $R_a(\mu\text{m})$
1	0.9	0.89	3.298	3.273
2	0.91	0.95	3.478	3.394
3	1.13	1.23	3.563	3.592
4	1.26	1.32	3.542	3.592
5	0.88	0.94	3.234	3.267
6	1.07	1.04	3.345	3.403
7	1.39	1.36	3.757	3.755
8	1.44	1.48	3.82	3.770
9	0.86	0.92	3.511	3.541
10	0.89	0.96	3.671	3.649
11	1.11	1.19	3.822	3.741
12	1.2	1.24	3.781	3.729
13	1.01	1.00	3.423	3.349
14	1.08	1.08	3.521	3.473
15	1.29	1.35	3.654	3.719
16	1.38	1.44	3.721	3.722
17	1.16	1.09	3.547	3.449
18	1.29	1.25	3.599	3.573
19	0.73	0.73	3.372	3.331
20	1.56	1.44	3.981	3.899
21	1.26	1.12	3.598	3.574
22	1.33	1.36	3.661	3.561
23	1.14	1.10	3.546	3.440
24	1.17	1.09	3.677	3.659
25	1.18	1.15	3.695	3.635
26	1.12	1.15	3.689	3.635
27	1.18	1.15	3.673	3.635
28	1.11	1.15	3.595	3.635
29	1.13	1.15	3.655	3.635
30	1.14	1.15	3.667	3.635

The regression analysis model of MR and R_a are presented in the Equations 3&4:

$$\text{MR} = 4.5 - 0.130 \text{ Vg} + 0.102 \text{ IP} - 0.781 \text{ WT} + 0.453 \text{ Pd} + 0.00125 \text{ Vg}^2 - 0.00375 \text{ IP}^2 + 0.0225 \text{ WT}^2 - 0.0125 \text{ Pd}^2 + 0.00094 \text{ Vg}^2 \text{ IP} + 0.0044 \text{ Vg}^2 \text{ WT} - 0.0031 \text{ Vg}^2 \text{ Pd} + 0.0100 \text{ IP}^2 \text{ WT} - 0.0100 \text{ IP}^2 \text{ Pd} + 0.0075 \text{ WT}^2 \text{ Pd} \quad (3)$$

S	R-sq	R-sq(adj)	R-sq(pred)
0.0809286	90.36%	81.36%	46.39%

$$R_a = -34.2 + 0.909 \text{ Vg} + 0.465 \text{ IP} + 0.656 \text{ WT} + 1.202 \text{ Pd} - 0.00772 \text{ Vg}^2 - 0.00125 \text{ IP}^2 - 0.0168 \text{ WT}^2 - 0.0213 \text{ Pd}^2 - 0.00752 \text{ Vg}^2 \text{ IP} + 0.00191 \text{ Vg}^2 \text{ WT} - 0.00153 \text{ Vg}^2 \text{ Pd} + 0.02122 \text{ IP}^2 \text{ WT} - 0.01484 \text{ IP}^2 \text{ Pd} - 0.0463 \text{ WT}^2 \text{ Pd} \quad (4)$$

S	R-sq	R-sq(adj)	R-sq(pred)
0.0680174	91.05%	82.69%	52.05%

R^2 values of MR and R_a are found to be 90.36% and 91.05%, respectively. Based on Table 3, the actual and predicted results of MR and R_a based on regression model are tabulated and comparison graphs are plotted.

Through the scatter plot, a line is drawn to represent the minimum distance between the line and each of the actual points. It's called a line of regression. The line of best fit is also called a regression line, since it is the line that best illustrates the relationship pattern between the variables. The results of comparison graphs represent a good relationship between the predicted and actual results.

4.2. ANOVA

ANOVA is a method used for statistical decision-making to identify any variations in the average output of the tested group of items (Maniraj et al., 2023). By using ANOVA, the major impact of process variables on the output characteristics can be calculated. By using 'higher-the-better' expectation for MR and 'lower-the-better' for R_a using MINITAB'18 software, the outcomes of factor responses are determined. The ANOVA outcome for MR shown in below Table 4 shows that IP and WT are parameters that make a major contribution to MR. ANOVA's calculated value is significant at 5% and 95% confidence.

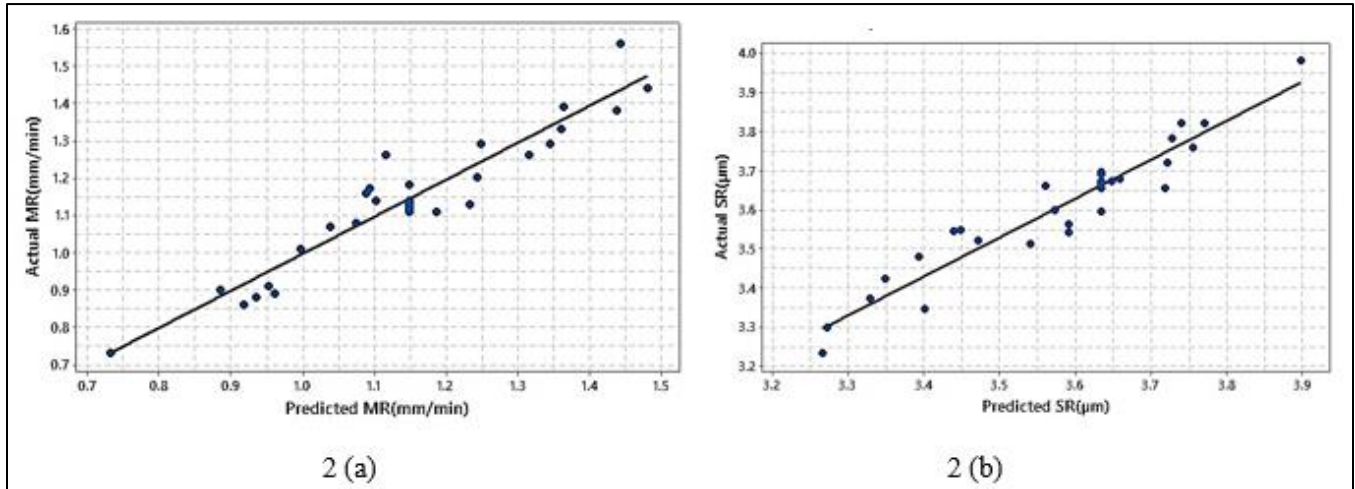


Figure 2: Comparison of actual with predicted results a) For MR b) For R_a

Table 4: ANOVA for MR

Source	DF	Adj SS	Adj MS	F-Value	P-value	% of Contribution
Model	14	0.9208	0.0657	10.04	0.000	90.36
Linear	4	0.8758	0.2189	33.43	0.000	85.95
Vg	1	0.0352	0.0352	5.38	0.035	3.46
IP	1	0.7561	0.7561	115.45	0.000	74.20
WT	1	0.0840	0.0840	12.83	0.003	8.24
Pd	1	0.0004	0.0004	0.06	0.804	0.04
Square	4	0.0292	0.0073	1.11	0.386	2.87
Vg*Vg	1	0.0006	0.0006	0.1	0.751	0.07
IP*IP	1	0.0061	0.0061	0.94	0.347	0.61
WT*WT	1	0.0138	0.0138	2.12	0.166	1.36
Pd*Pd	1	0.0042	0.0042	0.65	0.431	0.42
2-Way Interaction	6	0.0157	0.0026	0.4	0.867	1.55
Vg*IP	1	0.0002	0.0002	0.03	0.855	0.02
Vg*WT	1	0.0012	0.0012	0.19	0.672	0.12
Vg*Pd	1	0.0006	0.0006	0.1	0.762	0.06
IP*WT	1	0.0064	0.0064	0.98	0.339	0.63
IP*Pd	1	0.0064	0.0064	0.98	0.339	0.63
WT*Pd	1	0.0009	0.0009	0.14	0.716	0.09
Error	15	0.09824	0.006549			9.64
Lack-of-Fit	10	0.09371	0.009371	10.34	0.009	9.20
Pure Error	5	0.00453	0.000907			0.44
Total	29	1.01907				100.00

As per Table 4, contribution percentage for process parameters A, B, C and D on MR is found to be 3.46%, 74.20%, 8.24% and 0.04%, respectively. Therefore, the most influencing parameter that affects the MR is found to be peak current (B) which is at 74.20%.

ANOVA is used to analyze the effects on R_a under the influence of machining gap voltage, peak current, wire tension and dielectric pressure. Table 5 show the R_a results based on ANOVA. ANOVA's calculated value is significant at 5% and 95% confidence.

As per Table 5, contribution percentage for process parameters A, B, C and D on R_a is found to be 2.79%, 62.04%, 0.02% and 9.50%, respectively. Therefore, the most influencing parameter that affects the R_a is found to be peak current (B) which is at 62.04%. The error percentage is

significantly low at 0.44% and 0.84% for MR and SR, respectively.

5. EFFECT OF PROCESS VARIABLES ON MACHINING RATE

The effect of gap voltage and peak current on MR is presented in the figure 3. The gap voltage is increased from 51 to 59 volts and peak current is 2 to 10A. The increase in gap voltage increases the MR less linearly. The MR is found to be in the range of 0.6 to 0.9 mm/min for the change in gap voltage. The peak current is found to have significant effect of MR. The increase in peak current increases the MR to the maximum value. The increase in peak current contributes for generation intense spark between the wire and workpiece. These high energy instantaneous sparks melt and evaporate the workpiece contributing for high MR.

Table 5: ANOVA for R_a

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of Contribution
Model	14	0.7056	0.0504	10.89	0.000	91.05
Linear	4	0.5762	0.1440	31.14	0.000	74.35
Vg	1	0.0216	0.0216	4.68	0.047	2.79
IP	1	0.4808	0.4808	103.93	0.000	62.04
WT	1	0.0001	0.0001	0.04	0.848	0.02
Pd	1	0.0735	0.0735	15.91	0.001	9.50
Square	4	0.0372	0.0093	2.02	0.144	4.81
Vg*Vg	1	0.0261	0.0261	5.66	0.031	3.38
IP*IP	1	0.0006	0.0006	0.15	0.705	0.09
WT*WT	1	0.007705	0.007705	1.67	0.216	0.99
Pd*Pd	1	0.012398	0.012398	2.68	0.122	1.60
2-Way Interaction	6	0.092077	0.015346	3.32	0.028	11.88
Vg*IP	1	0.01446	0.01446	3.13	0.097	1.87
Vg*WT	1	0.000233	0.000233	0.05	0.826	0.03
Vg*Pd	1	0.00015	0.00015	0.03	0.859	0.02
IP*WT	1	0.028815	0.028815	6.23	0.025	3.72
IP*Pd	1	0.014102	0.014102	3.05	0.101	1.82
WT*Pd	1	0.034318	0.034318	7.42	0.016	4.43
Error	15	0.069395	0.004626			8.95
Lack-of-Fit	10	0.062894	0.006289	4.84	0.048	8.12
Pure Error	5	0.006501	0.0013			0.84
Total	29	0.775017				100.00

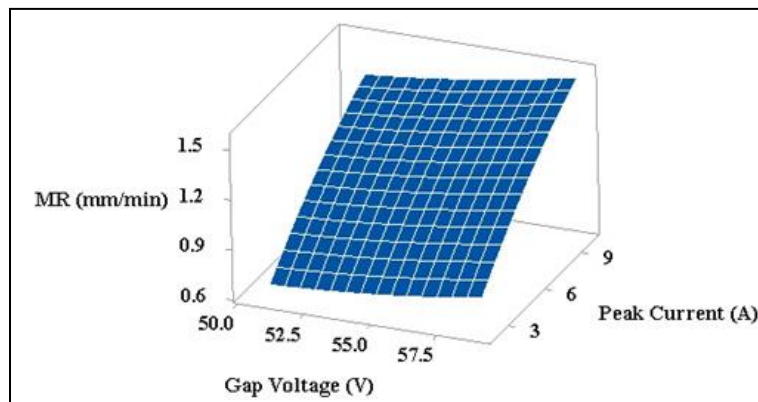


Figure 3: Combined effect of gap voltage and peak current on MR

Figure 4 shows the combined effects of wire tension and dielectric pressure. The wire tension is varied between 8 to 12 g and dielectric pressure is varied between 10 to 14 bar. The increase in wire tension increases the MR moreover the MR increases drastically at higher wire tension (Kannan et al., 2022). It is due to the fact that the higher wire tension reduces the bow effect contributing for higher MR (Mythili & Thanigaivelan, 2020). The dielectric pressure also attributes for higher MR, at high dielectric pressure the debris are flushed from the machining gap leading to improvement of MR. The higher wire tension and higher dielectric pressure contribute for higher MR. It is evident that wire tension and dielectric pressure show significant contribution on MR.

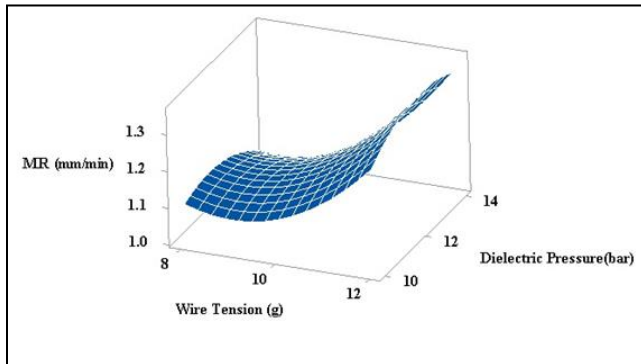


Figure 4: Combined effects of wire tension and dielectric pressure on MR

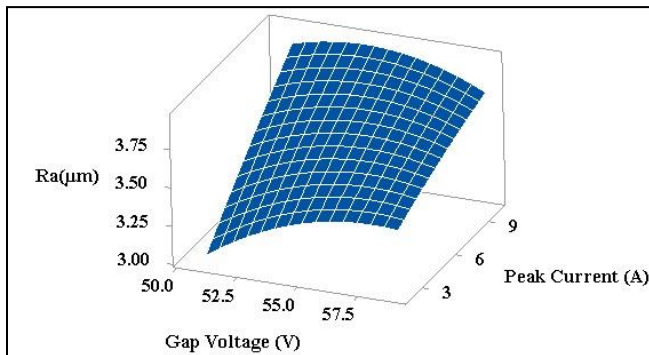


Figure 5: Combined effects of gap voltage and peak current on R_a

6. EFFECT OF PROCESS VARIABLES ON R_a

Figure 5 show that the increase in gap voltage increases the SR less linearly. The higher level of gap voltage and peak current shows higher SR. The peak current has the significant effect on the SR. The SR increases linearly with the peak current. The increase in peak current contributes for generation dense spark which results in bigger craters on the workpiece (Gökler & Ozanözgü, 2000). The presence of large size craters increases the SR. The scanning electron microscope image in figure 6 shows that the generation of craters on the machined surface.

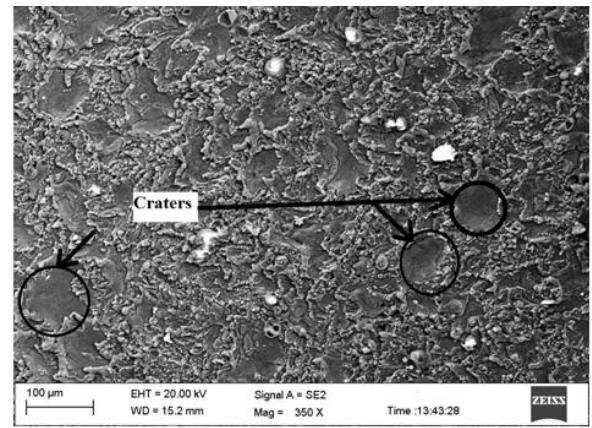


Figure 6: SEM of WEDMed surface

Figure 7 shows the combined effects of wire tension and dielectric pressure on R_a . The increase in wire tension increases the surface roughness. The increase in wire tension keeps the wire straight and helps to maintain the IEG. The proper maintaining of IEG creates high density spark leading to higher surface roughness. It is evident from the figure that higher wire tension and lower dielectric pressure produce higher R_a . The increase in dielectric pressure show less effect on R_a . The dielectric pressure clears the inter electrode gap (IEG) between the wire and workpiece and other than that it has no effect on the R_a (Han et al., 2007). Figure 8 shows the SEM image of the WEDM surface with fewer craters

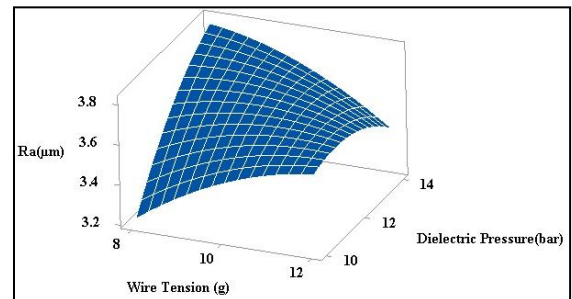


Figure 7: Combined effects of wire tension and dielectric pressure on R_a

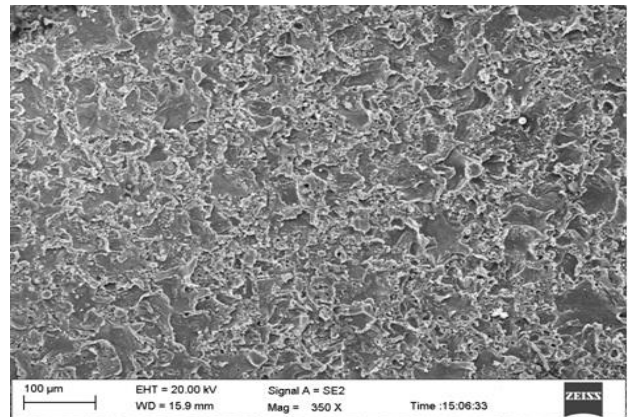


Figure 8: SEM of WEDMed surface with lesser craters

7. CONCLUSIONS

Detailed experiments with Central Composite Design (CCD) using RSM is planned and executed for the prepared specimen.

- Mathematical regression equation obtained for MR is:
 - $$\begin{aligned} \text{MR} = & 4.5 - 0.130 V_g + 0.102 \text{IP} - 0.781 \text{WT} \\ & + 0.453 \text{Pd} + 0.00125 V_g * V_g - 0.00375 \text{IP} * \text{IP} \\ & + 0.0225 \text{WT} * \text{WT} - 0.0125 \text{Pd} * \text{Pd} \\ & + 0.00094 V_g * \text{IP} + 0.0044 V_g * \text{WT} - 0.0031 V_g * \text{Pd} \\ & + 0.0100 \text{IP} * \text{WT} - 0.0100 \text{IP} * \text{Pd} + 0.0075 \text{WT} * \text{Pd} \end{aligned}$$
- Mathematical regression equation obtained for R_a is:
 - $$\begin{aligned} R_a = & -34.2 + 0.909 V_g + 0.465 \text{IP} + 0.656 \text{WT} \\ & + 1.202 \text{Pd} - 0.00772 V_g * V_g - 0.00125 \text{IP} * \text{IP} \\ & - 0.0168 \text{WT} * \text{WT} - 0.0213 \text{Pd} * \text{Pd} - 0.00752 V_g * \text{IP} \\ & + 0.00191 V_g * \text{WT} - 0.00153 V_g * \text{Pd} \\ & + 0.02122 \text{IP} * \text{WT} - 0.01484 \text{IP} * \text{Pd} - 0.0463 \text{WT} \end{aligned}$$
- R^2 values of MR and R_a are found to be 90.36% and 91.05%, respectively.
- The results of comparison graphs represent a good relationship between the predicted and actual results.
- The ANOVA outcome for MR shows that IP and WT are parameters that make a major contribution to MR. The contribution percentage for process parameters A, B, C and D on MR is found to be 3.46%, 74.20%, 8.24% and 0.04%, respectively. Thus, the largest influencing parameter that affects the MR is found to be peak current (B) which is at 74.20%.
- As per the contribution percentage for process parameters A, B, C and D on R_a is found to be 2.79%, 62.04%, 0.02% and 9.50%, respectively. Therefore, the most influencing parameter that affects the R_a is found to be peak current (B) which is at 62.04%. The error percentage is appreciably low at 0.44% and 0.84% for MR and SR, respectively.
- Based on the interaction graph, the raise in peak current enhances the MR to the maximum value. The higher wire tension and higher dielectric pressure contribute for higher MR.
- The peak current has the significant effect on the R_a . The raise in wire tension increases the R_a .

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CONFLICT OF INTEREST

There is no conflict of interest among the authors.

DATA AVAILABILITY

Corresponding authors will provide the data on request

REFERENCES

- Blair, R. W., Dunne, N. J., Lennon, A. B., & Menary, G. H. (2019). Multi-objective optimisation of material properties and strut geometry for poly (L-lactic acid) coronary stents using response surface methodology. *PLoS One*, 14(8), e0218768.
- Box, G. E., & Hunter, J. S. (1957). Multi-factor experimental designs for exploring response surfaces. *The Annals of Mathematical Statistics*, 195-241.
- Dhilip, J. D. J., Ganesan, K. P., & Sivalingam, V. (2023). Machinability studies and optimization of process parameters in wire electrical discharge machining of aluminum hybrid composites by the VIKOR method. *Journal of Materials Engineering and Performance*, 1-16.
- Gökler, M. İ., & Özanozğü, A. M. (2000). Experimental investigation of effects of cutting parameters on surface roughness in the WEDM process. *International journal of Machine tools and manufacture*, 40(13), 1831-1848.
- Han, F., Jiang, J., & Yu, D. (2007). Influence of machining parameters on surface roughness in finish cut of WEDM. *The International Journal of Advanced Manufacturing Technology*, 34, 538-546.
- Ho, K., Newman, S., Rahimifard, S & Allen, R 2004, 'State of the art in wire electrical discharge machining (WEDM)', *International Journal of Machine Tools and Manufacture*, vol. 44, no. 12-13, pp. 1247-1259.
- Kaliappan, S., Mohanamurugan, S., & Nagarajan, P. K. (2020). Numerical investigation of sinusoidal and trapezoidal piston profiles for an IC engine. *Journal of Applied Fluid Mechanics*, 13(1), 287-298. <https://doi.org/10.29252/jafm.13.01.29881>
- Kannan, P. R., Periasamy, K., Pravin, P., & Kumaar, J. V. (2022). An experimental investigation of wire breakage and performance optimisation of WEDM process on machining of recycled aluminium alloy metal matrix composite. *Materials Science-Poland*, 40(3), 12-26.
- Kumar, G. P., Thanigaivelan, R., Arunachalam, R. M., & Paramasivam, P. (2014). Experimental investigation of edm processing parameters on machining al6063-12% sic-5% gr using response surface methodology. *High Temperature Material Processes*, 18(1-2), 27-43.
- Kumar, H, Manna, A & Kumar, R 2018, 'Modeling and desirability approach-based multi-response optimization of WEDM parameters in machining of aluminum metal matrix composite', *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, vol. 40, no. 9, pp. 1-19.
- Maniraj, S., Thanigaivelan, R., Gunasekaran, K., & Saravanan, K. G. (2023). Optimization of process parameters in electrochemical micromachining of amcs by using different techniques of weight evaluation. *Advances in Materials Science and Engineering*, 2023(1), 1366857.
- Maurya, S. K., Susheel, C. K., & Manna, A. (2024). Experimental investigation of wire EDM parameters during machining of fabricated hybrid Al/(SiC+ ZrO₂+ NiTi)-MMC. *Advances in Materials and Processing Technologies*, 10(2), 187-197.
- Mythili, T., & Thanigaivelan, R. (2020). Optimization of wire EDM process parameters on Al6061/Al₂O₃ composite and its surface integrity studies. *Bulletin of the polish academy of sciences technical sciences*, 1403-1412.
- Patil, N. G. (2023). Determination of optimal performance in wire electrical discharge machining of Al/Al₂O₃/22p composites using response surface methods and grey relational analysis. *Australian Journal of Mechanical Engineering*, 21(4), 1259-1271.
- Prakash, J. U., Sivaprakasam, P., Juliyana, S. J., Ananth, S., Rubi, C. S., & Sadhana, A. D. (2023). Multi-objective optimization using grey relational analysis for wire EDM of aluminium matrix composites. *Materials Today: Proceedings*, 72, 2395-2401.
- Pratheesh, K., & Monikandan, V. V. (2023). Investigation and optimization of tribo-mechanical behavior of squeeze casted Al-Si piston alloy-based metal matrix composite using response surface methodology and neural network. *Surface Review and Letters*, 30 (12), 2350082. <https://doi.org/10.1142/S0218625X23500828>.
- Senthil Kumar, S., Sudhakara Pandian, R., Pitchipoo, P., Senthilkumar, T. S., & Ponnambalam, S. G. (2023). Investigation of wear and wire electrical discharge machining characteristics of Al-Mg-MoS₂ composites using response surface method. *Journal of testing and evaluation*, 51(2), 828-857.

- Sudhagar, S., Gopal, P. M., Maniyarasan, M., Suresh, S., & Kavimani, V. (2024). Multi-objective optimization of machining parameters for Si₃N₄-BN reinforced magnesium composite in wire electrical discharge machining. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 1-16.
- Venugopal, P., Saravanan, K. G., & Thanigaivelan, R. (2023). Performance analysis of edm on grey cast iron using rsm and topsis method. *Appl. Eng. Lett.*, 8, 10-16.
- Vinoth, S., Rajasekar, C., Sathish, P., Sureshkumar, V., Yasminebegum, A., Ahammad, S. H., & Girimurugan, R. (2023, May). Optimization of process parameters on wire cut electrical discharge machining and surface integrity studies of AA6070/MgO composites. In *Journal of Physics: Conference Series* (Vol. 2484, No. 1, p. 012012). IOP Publishing.