STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Special Issue 6, 2025
DOI (Journal): 10.37591/JoPC

https://journals.stmjournals.com/jopc

Research JoPC

Optimization of EDM Machining Characteristics of Reinforced Aluminium Metal Matrix Composites by Taguchi

Rajkumar Subburathinam[1,*], Mohamed Hamdan A.[2], Sathiyalingam Kannaiyan[3], D. Madesh[4], Vijayaraj T.[5]

Abstract

Aluminium alloys metal matrix composites (AMMC) play a vital role in various industries, such as aerospace and automobiles. This study investigates the machining characteristics of AL8079 - based composites reinforced with 15 wt. % TiB_2 and 5 wt. % MoS_2 using Electrical Discharge Machining (EDM). The machining process was optimized using the L9 orthogonal array (OA) Taguchi - based design of experiments, and input parameters were considered at three levels, which included pulse - duration (T_{on}) (100 µs, 200 µs, and 300 µs), current (A) (4 amps,6 amps, and 8 amps), and pulse - interval (T_{off}) (40 µs, 60 µs, and 80 µs). The response parameters for optimization were metal removal rate (MRR) and Tool Wearing Rate (TWR). The EDM machining was conducted using copper electrodes of 10 mm diameter with kerosene as a dielectric fluid employed during the process. The optimization revealed that high current (8 A), high pulse - duration (T_{on}), (300 µs), and low pulse-interval (T_{off}) (40 µs) contributed to better MRR with contributions of 41.94%, 34.8%, and 23.18% respectively. The low current (4 A), low pulse - duration (100 µs), and high pulse - interval (T_{off}) (40 µs), which produce lower TWR with contributions of 55.85%, 29.68%, and 14.43% respectively.

Keywords: AL8079, TiB_2, MoS_2, Taguchi method, Electrical Discharge Machining (EDM)

INTRODUCTION

Composites are advanced materials that contain two or more different elements in order to achieve superior properties when compared to the individual materials[1]. The main components of a composite are the matrix and reinforcement which acts as the binder and provide strength and stiffness to improve the properties[2]. Composites can be widely classified into four major categories such as polymer-based matrix composites (PMCs), ceramic-based matrix composites (CMCs), metal-based matrix composites (MMCs) and carbon-carbon based composites (CCC) based on the type of material used[3]. Aluminium metal matrix composites are familiar for their superior properties, like lightweight, good strength-to-weight ratio, and excellent corrosion resistance, to fulfil industrial requirements [4].

The mechanical properties of aluminium alloys can be strengthened by reinforcing them with ceramics, carbides, and other solid lubricant materials to develop an advanced aluminium metal matrix composite (AMMC) [5]. Commonly used reinforcements are silicon carbide (SiC), alumina

***Author for Correspondence**
Rajkumar Subburathinam

[1,5]Assistant Professor (SG), Department of Aeronautical Engineering, KCG College of Technology, Chennai, Tamil Nadu, India
[2,4]Assistant Professor, Department of Aeronautical Engineering, Nehru Institute of Engineering and Technology, Coimbatore, Tamil Nadu, India
[3]Postdoctoral Researcher, Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taiwan.

Received Date: July 22, 2025
Accepted Date: August 14, 2025
Published Date: November 26, 2025

Citation: Rajkumar Subburathinam, Mohamed Hamdan A., Sathiyalingam Kannaiyan, D. Madesh, T. Vijayaraj. Optimization of EDM Machining Characteristics of Reinforced Aluminium Metal Matrix Composites by Taguchi. Journal of Polymer and Composites. 2025; 13(Special Issue 6): S939–S951p.

(Al_2O_3), and boron carbide (B_4C), which improve hardness and stiffness, while graphite (Gr) and molybdenum disulfide (MoS_2) provide self-lubricating properties and improve machinability[6, 7].

Ravi Kumar et al. [8] investigated aluminium alloy (A-6063) with titanium carbide particles reinforced composites, and found while addition of titanium carbide increased the density, hardness and tensile strength of composites up to the level of 7.82%, 20% and 19.53% respectively. Kannan et al.[9] studied with the machining process involved using an AL7075 nanocomposite that was reinforced with 0.5 weight percent boron nitride (BN) and 1 weight percent alumina (Al_2O_3) which acted as a nano-lubricant to achieve a good surface finish. The presence of reinforcements like carbon-nanotube (CNT), nano-Silicon Carbide, and graphene improves the surface finish and improves the machinability because of less frictions[10]. Han et al.[11] Aluminium 6061 alloy with 10 % of TiB_2, graphite and different composition of MoS_2 reinforcement and concluded that 20 % of MoS_2 reduces the wear rate by 40 % and Co-efficient of Friction (CoF) by 54 %. The inclusion of TiB_2 and MoS_2 as reinforcements improves hardness, wear resistance, and self-lubricating properties, making these composites suitable for high-performance applications [12]. Thus, Table 1 shows the various elements present on aluminium alloys widely used in the various industries.

AL8079, which exhibits excellent formability, light weight, and good corrosion resistance, is suitable for modern industries due to these characteristics. The mechanical properties of MMCs can be enhanced by alloying with TiB_2 and MoS_2, resulting in hybrid MMCs with superior properties. TiB_2 (Titanium Diboride) is a ceramic-based material that has a good wear and corrosion resistance and improved hardness. Due to these properties using TiB_2 as a reinforcement increases the overall characteristics of the aluminium alloy. MoS_2 (Molybdenum Disulfide), is a soft solid lubricant that is used in the composites to reduce friction and increase the self-lubrication properties, which enhance the life of the tools during machining and produces good surface finish on the products[11-14].

The stir casting process is mostly chosen for fabricating aluminium metal matrix composites (AMMCs) because it produces a uniform distribution of reinforcement and most economical production. The best characteristics of composites lie on factors such as the stirring speed, time, preheating of reinforcements, and the wettability of reinforcements with the aluminium matrix and reduces clustering with good bonding.[15–17].

Electrical Discharge Machining (EDM) is a suitable machining method for complex geometries without producing stress on the materials. It can be used on almost all kinds of materials, especially hard and brittle materials, which are challenging to machine through the normal machining process. The characteristics of the machining process, such as the metal removal rate (MRR), Tool Wear Rate (TWR), and surface roughness, are key response parameters that are influenced by the input parameters, such as the pulse-duration, pulse-interval (T_{off}), voltage, and current [17, 18]. The Taguchi optimization method is widely used to optimize the process parameters involved in the machining processes. In particular, the L9 orthogonal-array (OA) Taguchi methods provide efficient experimentation with a smaller number of trails and the most robust results [19- 21].

Table 1. Elements configuration of aluminium alloys.

Alloys \ Wt.%	Al	Fe	Si	Zn	Mg	Cu	Ti	Mn	Cr	Others
5052	96.1	0.40	0.25	0.10	2.50	0.10	0.15	0.10	0.15	0.15
6061	96.52	0.70	0.60	0.25	1.00	0.28	0.15	0.15	0.20	0.15
6063	98	0.35	0.40	0.10	0.60	0.10	0.10	0.10	0.10	0.15
7075	89.19	0.41	0.13	5.70	2.30	1.50	0.05	—	0.18	0.54
8011	97.95	0.75	0.82	0.10	0.05	0.10	0.08	—	—	0.15
8079	97.04	1.4	0.3	0.1	0.2	0.6	0.2	—	—	0.16

Through the literature it is found that Al8079 was used in the limited applications because of the limitation in properties. The combination of Al8079 with TiB_2 and MoS_2 Composites were not found in the literature studies; hence, this study experiments Al8079 with reinforcements of TiB_2 and MoS_2, the optimization was done with L9 OA Taguchi based design to investigate the process parameters such as current, Pulse-duration and pulse-interval (T_{off}) in order to increase the response parameters MRR and reduce the TWR.

EXPERIMENTATION

Materials

AL8019 is capable of producing good ductility, moderate tribological, mechanical, and corrosion properties. Thus, this alloy has been used for this study as a matrix material. Hard reinforcement TiB_2 and soft reinforcement MoS_2 are used for the manufacturing of composites with aluminium alloy. TiB_2 which improves the tensile, impact, compressive strength, wear, and corrosion resistance of the matrix material [22, 23]. The hexagonally structured MoS_2 is used to reduce the coefficient of friction acting turbo film layer in between the two surfaces of elements. The elements presented in the TiB_2& MoS_2 is shown in Table 2.

Fabrication

The stir casting process was employed for the manufacturing of Al8079-based composite materials with preheated reinforcements at 250°C for the time period of 30 minutes in the preheater setup. We procured the alloy in the form of cylindrical rods and sized it into small pieces. The graphite crucible furnace was set at a temperature of 750^0C to melt the aluminium alloys, then preheated reinforcements and 1 wt% of magnesium were included with the molten alloy, which increases the wettability between the matrix and reinforcements [15].The composition was stirred at the speed of 600 rpm for the time period of 25 minutes and metal degassing tablets were added to prevent the oxide formation while casting. The mixed Al8079 MMC was cast into samples according to the specifications.

EDM Process

The machining behavior of the manufactured AL8079 composites was analyzed by using EDM process. Optimized EDM machining process metrics were done by using Taguchi design with Grey Relation Analysis (GRA). The Cu electrode, which provides a good surface finish with low electrode wear and it is used in this investigation[24]. The EDM process conditions are detailed in Table 3 and the experimental setup of EDM is shown in Figure 1.

Table 2. Elements of TiB_2 and MoS_2.

TiB_2		MoS_2	
Elements	**Wt.%**	**Elements**	**Wt.%**
Ti	67.52	Mo	59.84
B	31.10		
O	0.46	S	40.15
N	0.28	Fe	0.005
C	0.23		
Fe	0.09	Cu	0.001

Table 3. EDM process conditions

Processing mechanism	Controlled erosion
Peak voltage	30- 250 V
Frequency of spark	200 – 500 kHz
SPC	2-10 W/mm^3/min
Gap of spark	0.010- 0.500 mm
Tool material	Copper

Dielectric fluid	Kerosene

Figure 1. EDM Experimental Setup

Table 4. L9 OA for EDM parameters optimization

Trial No.	Pulse-Duration T_{on} (μs) A	Pulse-Interval T_{off} (μs) B	Current (Amps) C
1	100	40	4
2	100	60	6
3	100	80	8
4	200	40	6
5	200	60	8
6	200	80	4
7	300	40	8
8	300	60	4
9	300	80	6

The input parameters for the EDM process optimization were pulse duration (100, 200 and 300), pulse interval (40, 60, and 80), and current (4, 6, and 8), and the response parameters were metal removal Rate (MRR) and Tool Wear Rate (TWR). The L9 OA design was used for optimization, which was performed using the GRA technique. The L9 OA for optimizing the EDM parameters is shown in Table 4. The MRR was calculated for each L9 OA condition by calculating the weight difference of the composite workpiece specimen before and after making every hole. The EDM drilling was performed to 0.5-mm thickness. The tool wear rates were computed from the weight difference on copper electrode earlier and afterward making every hole.

RESULT AND DISCUSSION

Machining Characteristics

The specimen combination of AL8079 with 15 wt% TiB_2 and 5wt% of MoS_2 composite are subjected to the machining characteristics by using Electrical Discharge Machining. The EDM process parameters of AL8079-based composites are optimized by using Taguchi design based. The pulse-duration (T_{on}), pulse-Interval (T_{off}), and current were chosen as input parameters for optimization of EDM parameters of AL807915wt.%TiB_2/5wt.%MoS_2 composite. The metal removal

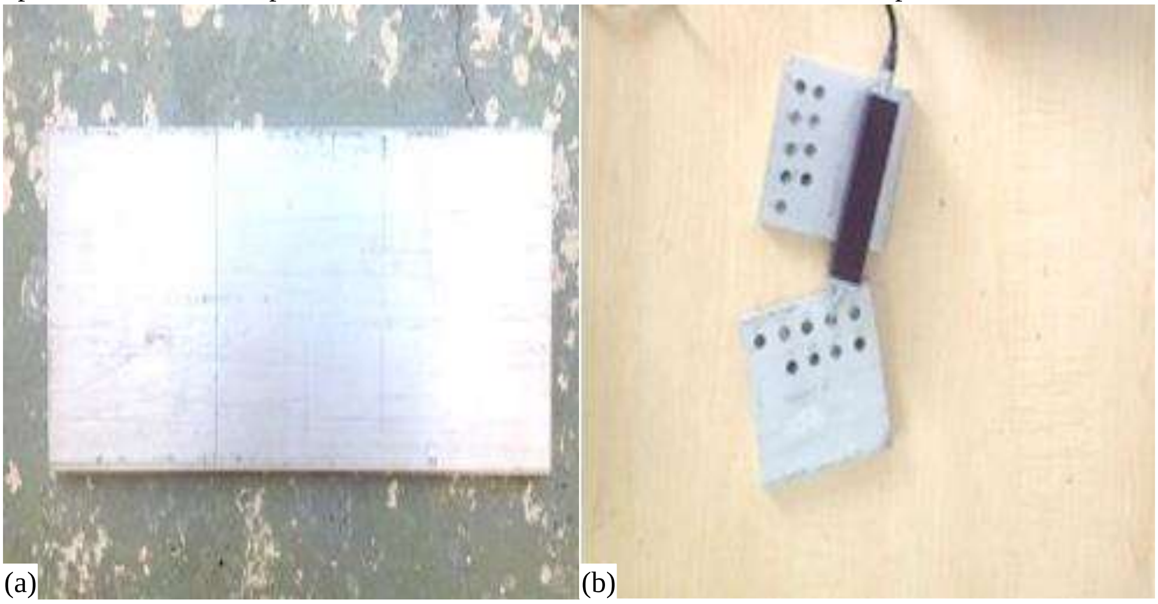

Figure 2. EDM specimens

Table 5. L9 with EDM input and response parameters

Trial No.	Pulse-Duration T_{on} (µs)	Pulse-Interval T_{off} (µs)	Current (Amps)	MRR (mm^3/min)	TWR (mg/min)
1	100	40	4	15.28	0.52
2	100	60	6	16.31	0.72
3	100	80	8	17.22	0.92
4	200	40	6	22.71	1.22
5	200	60	8	23.78	1.42
6	200	80	4	13.56	0.42
7	300	40	8	30.23	1.92
8	300	60	4	19.31	0.92
9	300	80	6	20.28	1.12

and tool wear rates were the response parameters for this optimization. A 10-mm-diameter copper electrode was used for drilling the AL8079 composite. The specimens were weighed earlier and later of every machining experiment in order to compute the metal removal rate and the copper electrode is also weighed in the same manner for calculating the tool wear rate for every experiments likewise two sets of experiments were conducted for each combination of input parameters and the specimens for EDM are shown in Figure 2.

$$MRR\left(\frac{mm^3}{min}\right) = \frac{SW_i - SW_f\ (g)}{\rho_s (g/mm^3) \times T_{mt}\ (min)} \tag{1}$$

$$TWR\left(\frac{mg}{min}\right) = \frac{TW_i - TW_f\ (mg)}{T_{mt}\ (min)} \tag{2}$$

SW_i&$SW_f$are the early machining weight and after machining weight of the specimens in grams, and TW_i&$TW_f$are the early machining weight and after machining weight of the tool in milli grams.$\rho_s$are the density of specimen material and $T_{mt}$is the machining duration for each hole on the specimens in minutes. The MRR and TWR are calculated using the formula 1 & 2 and the average value of MRR and TWR are tabulated. The calculated response parameters with L9 with the input parameters after machining and is tabulated in Table 5 for optimization.

Optimization of EDM Process Parameters in MRR

The OA L9 input and response parameters of EDM were optimized using the Taguchi approach using Minitab 19 software. The response table for optimizing the input parameters of EDM is exposed in Table 6. The input process matrix sequences influenced by EDM on AL8079/15wt.%TiB_2/5wt.%MoS_2 is current, pulse positive cycle time and pulse negative cycle time for MRR.

Figure 3 displays the main effect plot of the means for the MRR, and the optimized input parameters of EDM on AL8079/15wt.%TiB_2/ 5wt.%MoS_2 composites is high level of current (8 amps), minimum level of pulse-Interval (40 μs) and high level of pulse-Duration (300 μs). The enhanced pulse duration increases the metal removal rate by enhancing heat generation in the Material. The increasing pulse-Interval (T_{off}) time diminishes the MRR while drilling by using this machining process. The increasing pulse off time decreased by the duration of machining and it causes to reduce the removal rate on materials of AL8079/15wt.%TiB_2 /5wt.%MoS_2 composite.

The contour plot for pulse positive cycle time, pulse negative cycle time and current is shown in Figure 4. The enhancement of pulse-duration (T_{on}) and current increases the removal rate of AL8079/15wt.%TiB_2 /5wt.%MoS_2 composite by increasing the duration of machining time which can be found in Figure 4(a), the long duration of machining enhances the size of the cavity formation and

Table 6. Response Table for Means for MRR

Level	Pulse-Duration (μs) A	Pulse-Interval (μs) B	Current (Amps) C
1	16.27	**22.74**	16.05
2	20.02	19.80	19.77
3	**23.27**	17.02	**23.74**
Delta	7.00	5.72	7.69
Rank	2	3	1

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

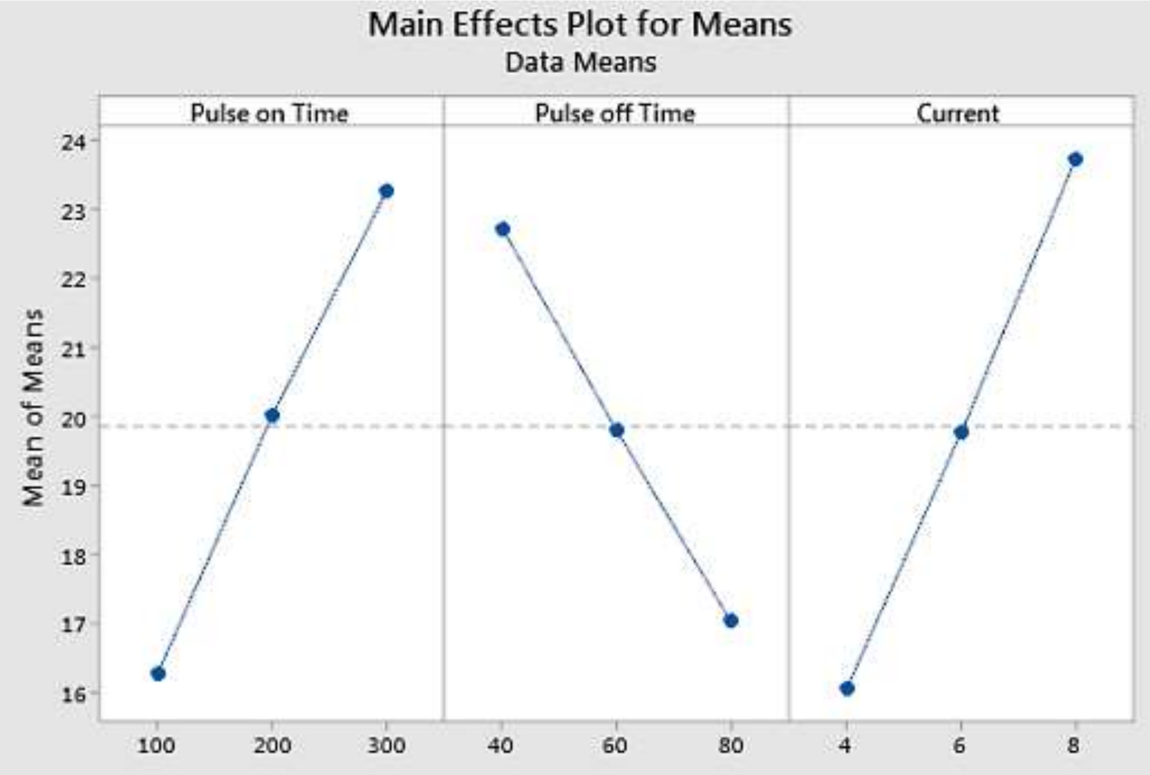

Figure 3. Main Effect Plot of Means for MRR

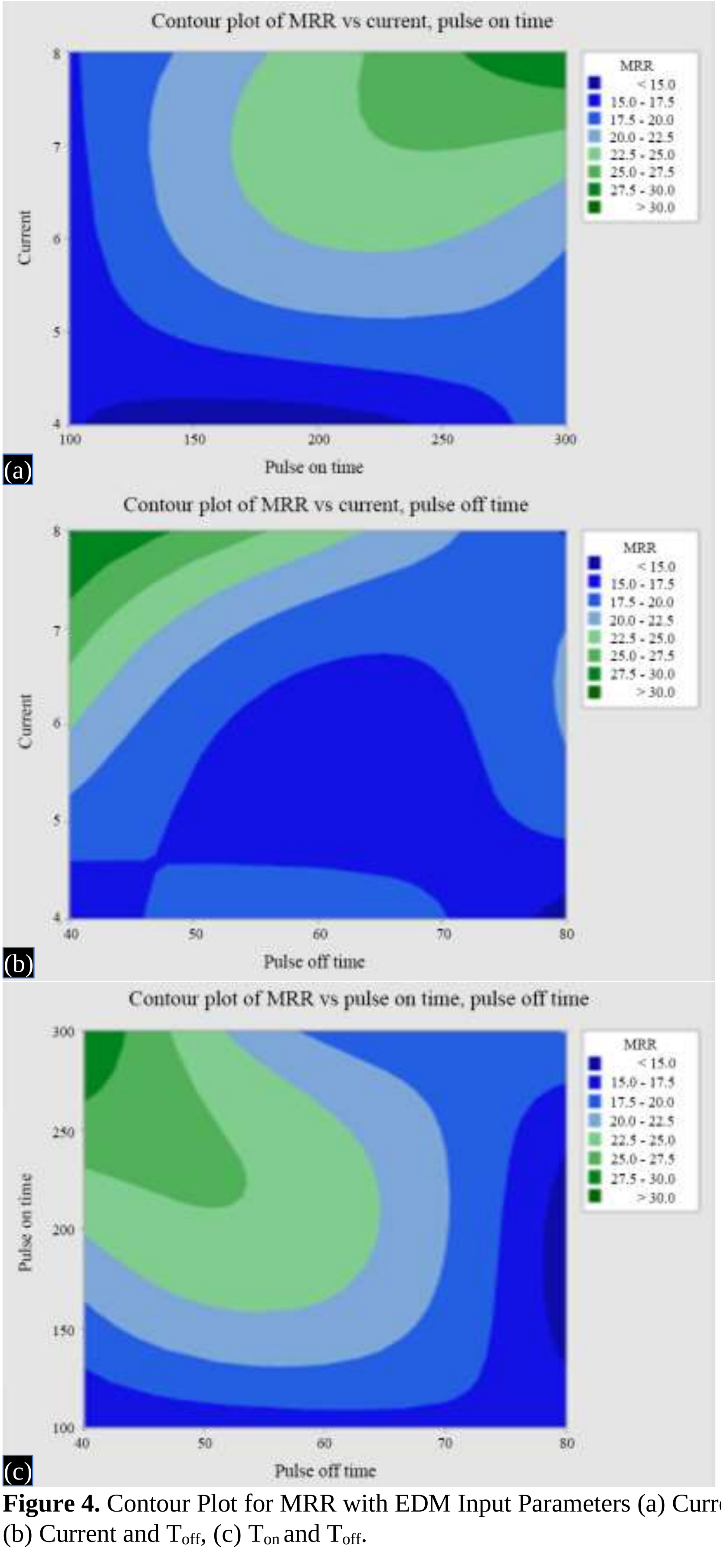

Figure 4. Contour Plot for MRR with EDM Input Parameters (a) Current and T_{on}, (b) Current and T_{off}, (c) T_{on} and T_{off}.

Table 7. Factor Information for MRR

Factor	Type	Levels	Values
Pulse-Duration (µs)	Fixed	3	100, 200, 300
Pulse-Interval (µs)	Fixed	3	40, 60, 80
Current (amps)	Fixed	3	4, 6, 8

Table 8. Analysis of Variance for MRR

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Pulse-Duration (µs)	2	73.690	36.8450	499.71	0.002	34.61
Pulse-Interval (µs)	2	49.090	24.5452	332.89	0.003	23.25
Current (amps)	2	88.815	44.4074	602.27	0.002	42.07
Error	2	0.147	0.0737	-	-	0.07
Total	8	211.743	-	-	-	100

it causes to high MRR. In Figure 4(b) contour plot shows that high level of negative pulse cycle reduces the MRR and which can be compensated by increasing the current for achieving the high MRR. T_{on} & T_{off} contour plot Figure 4(c) shows the positive cycle improves and negative cycle decreases the metal removal rate. The factor information for EDM process parameter optimization of AL8079/15wt.%TiB_2 /5wt.%MoS_2 composite is displayed in Table 7.

The ANOVA table for MRR is displayed in Table 8, which describes the parameters in source such as Pulse-Duration (µs), Pulse-Interval (µs), and Current (amps) respectively, and find the consequence of the input matrices on response parameters and contribution of process parameters on response parameters.

Degrees of freedom, DF=L-1 (3)

Adjusted Sum of Squares (Adj SS) = $\sum_{i=1}^{a} n_i (y_i - y)^2$ (4)

Mean Square for the Factor (Adj MS) =$\frac{Adj\ SS}{DF}$ (5)

Where,
L is number of levels for that factor
y_i= mean MRR at level i of factor
y = grand mean MRR
n_i= number of observations at that level

The p-value of all EDM process parameters used in the optimization is less than 0.05 and hence all input EDM process parameters are significant. The extremely small error term 0.07% indicates that all variation in MRR is obtained by the considered parameters. The high F-values which ranges from 332.89 to 602.27 confirms the strong influence of the parameters. The percentage contribution of current, pulse duration (T_{on}) and pulse Interval (T_{off}) on MRR is 42.07, 23.25 and 34.61 % respectively and it is shown in Figure 5.

EDM Process Parameters Optimization for TWR

The response table for TWR is exposed in Table 9. The influenced sequence for optimization of EDM input parameters is the current, pulse positive cycle time and pulse negative cycle time. The optimized EDM input parameter combination includes a low current (4 amps), low level of pulse-duration (T_{on}) (100 µs) and high level of pulse-Interval (T_{off}) (40 µs). The main effect plot for means of TWR is depicted in Figure 6. The enhancement of current increases the Tool Wear Rate by formation high energy spark and formation of high energy spark causes to maximize the tool wearing rate. The raising of pulse-duration (T_{on}) enhances the wearing rate of tool by increasing the machining time.

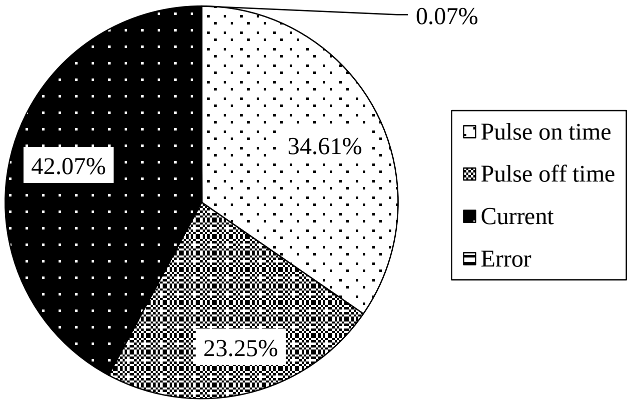

Figure 5. Contribution percentage of input parameters on MRR

Table 9. Response Table for Means of TWR

Level	Pulse-Duration T_{on} (µs)	Pulse-Interval T_{off} (µs)	Current (Amps)
1	0.7367	1.2200	0.6167
2	1.0167	1.0400	1.0400
3	1.3200	0.8133	1.4167
Delta	0.5833	0.4067	0.8000
Rank	2	3	1

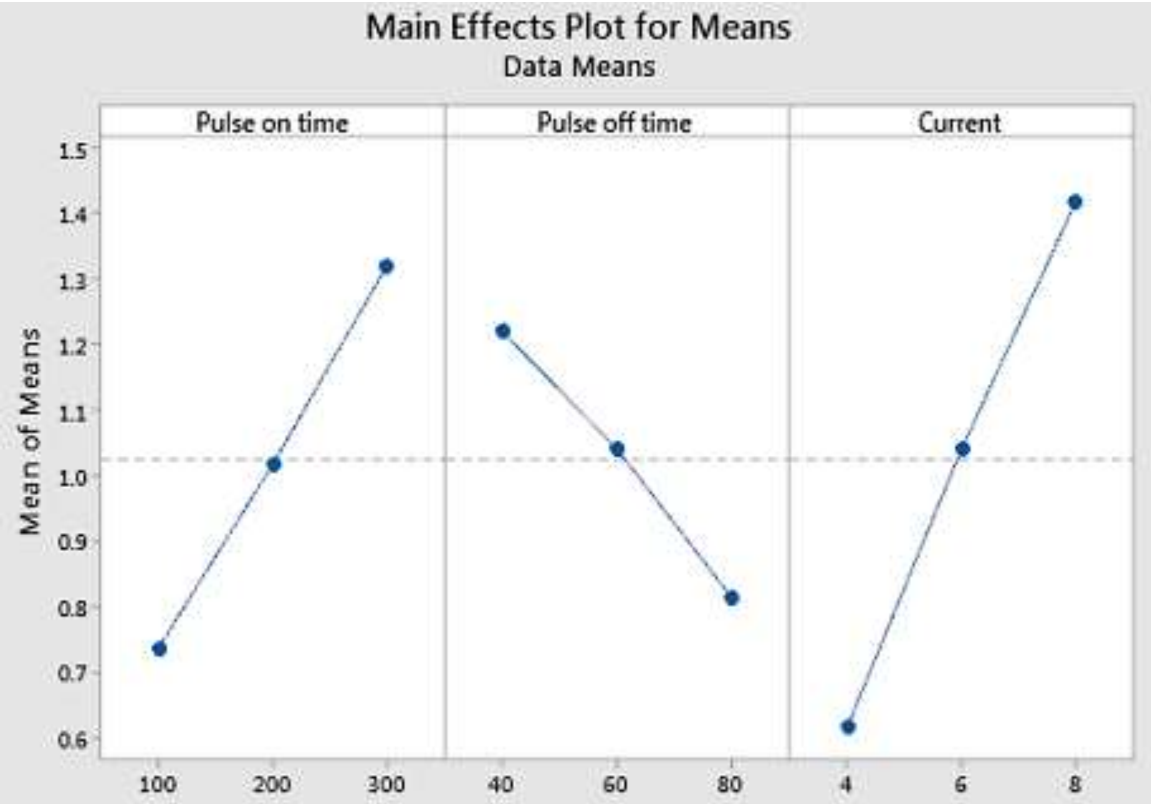

Figure 6. Main Effect Plot for Means of TWR

The long duration of machining time raises the Tool Wearing Rate. The enhanced pulse-Interval (T_{off}) reduces the tool wear rate by reducing the duration of machining time. The decreasing of machining time duration decreases the tool wearing rate.

Journal of Polymer & Composites
Volume 13, Special Issue 6
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

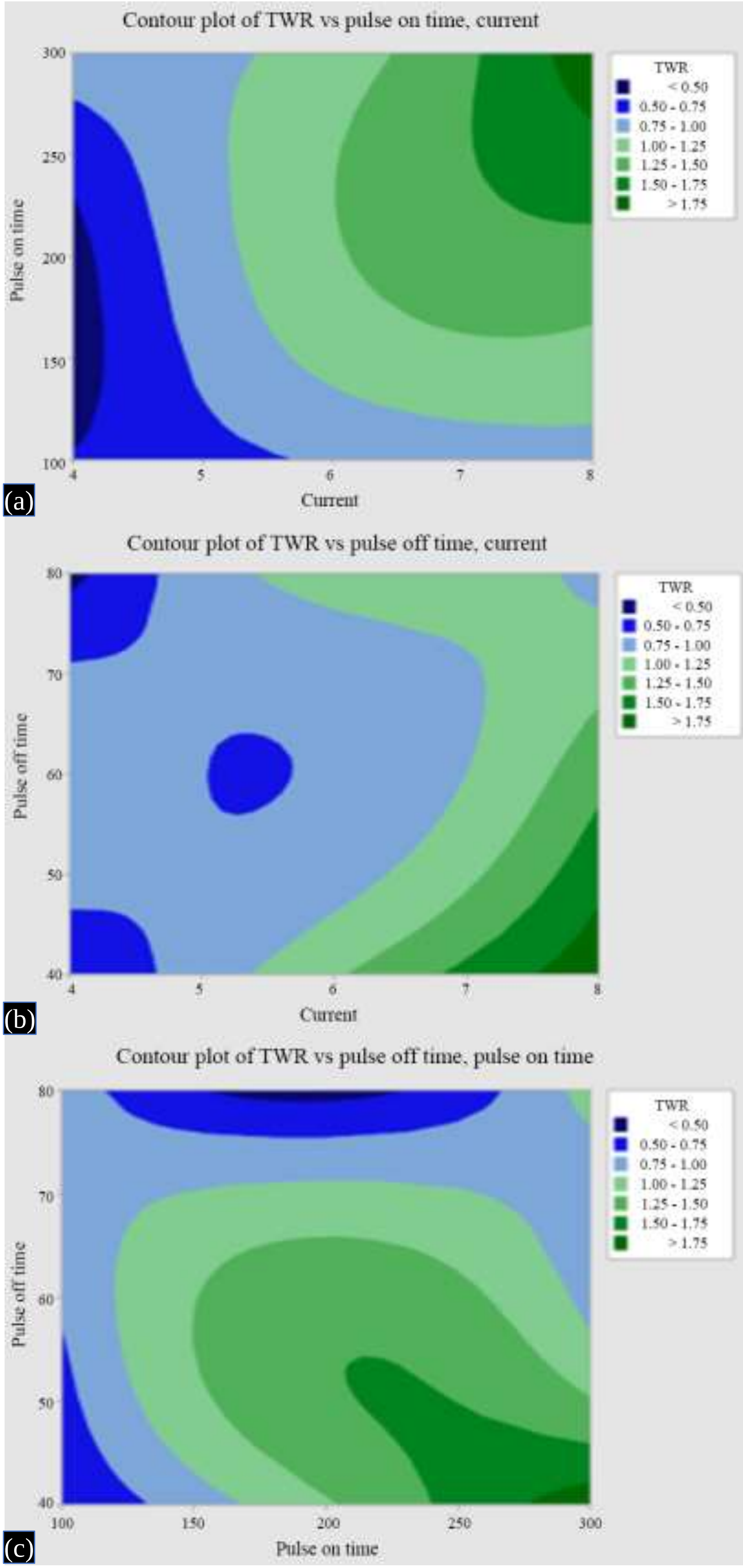

Figure 7. Contour plot for TWR (a) Current and T_{on} (b) Current and T_{off} (c) T_{on} and T_{off}

The relationship between the pulse positive cycle time, pulse negative cycle time and current with Tool Wear Rate is shown in Figure 7(a)–(c). The analysis of the contour plot of TWR it shows that influence of current at high level increases the tool wear rate and it can be minimized by reducing the positive pulse cycle and increasing pulse-Interval (T_{off}). The factor information for the TWR is displayed in Table 10.

The ANOVA results for TWR are presented in Table 11. The ANOVA is conducted to find the implication of the EDM input parameters on TWR and to determine the contribution of process parameters in percentage of EDM on TWR. The significance of the input parameters was confirmed by the P value, and it is lesser than 0.05. The percentage contribution of pulse-Duration, current, and pulse-Interval on TWR are 55.85%, 29.68% and 14.43% respectively and it is shown in Figure 8. The confirmation table for MRR and TWR is displayed in Tables 12 and 13. The optimized parameters for MRR are (A3B1C3) Pulse-Duration (A) at level 3, Pulse-Interval (B) at level 1, and Current (C) at level 3 and Optimized parameters for TWR (A1B3C1) are at the levels of 1, 3 and 1 for Pulse-Duration (A), Pulse-Interval (B) and Current (C). The MRR and TWR for optimized EDM input parameter is 35.2 mm^3/min and 0.44 mg/min, respectively.

Table 10. Factor Information for TWR

Factor	Type	Levels	Values
Pulse-Duration (Ton)	Fixed	3	100, 200, 300
Pulse-Interval (T_{off})	Fixed	3	40, 60, 80
Current	Fixed	3	4, 6, 8

Table 11. ANOVA for TWR

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Pulse-Duration T(on) µs (A)	2	0.51069	0.255344	741.32	0.001	29.68
Pulse-Interval (T_{off}) µs (B)	2	0.24916	0.124578	361.68	0.003	14.43
Current amps(C)	2	0.96109	0.480544	1395.13	0.001	55.85
Error	2	0.00069	0.000344	-	-	0.04
Total	8	1.72162	-	-	-	100

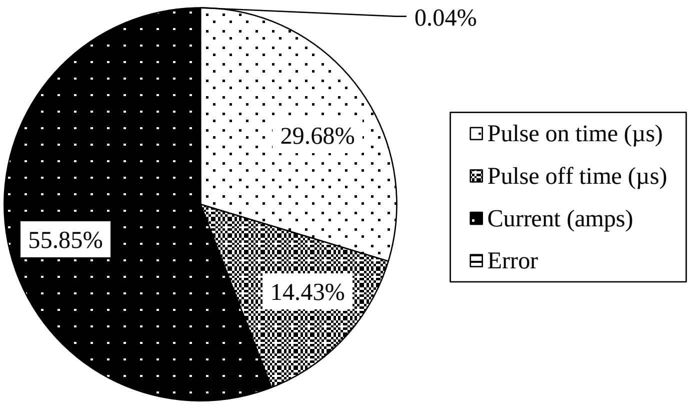

Figure 8. Contribution Percentage on TWR

Table 12. Confirmation Table for MRR

Parameters	MRR (mm^3/min)
Initial settings (A1B1C1)	15.28
Optimized parameters for MRR (A3B1C3)	35.2

Table 13. Confirmation Table for TWR

Parameters	TWR (mg/min)
Initial settings (A1B1C1)	0.52
Optimized parameters for TWR (A1B3C1)	0.44

CONCLUSION

AL8079 is a low-cost aluminium alloy and excellent formability characteristic, when is reinforced with elements such as TiB_2 and MoS_2 improves the properties similar to other aluminium used in the industry and hence in this study AL8079 with 15 wt.% TiB_2 and 5 wt.% MoS_2-based composite specimens was prepared and machined using electrical discharge machining. The L9 OA based Taguchi design were developed in order to analyses the machining characteristics of AL8079 based composites.

- The chosen input parameters were pulse-duration (T_{on}) (100 µs, 200 µs, and 300 µs), current (4 amps,6 amps, and 8 amps), and pulse-interval (T_{off}) (40 µs, 60 µs, and 80 µs). The response parameters for EDM optimization were metal removal Rate and Tool Wear Rate, and the tool was a copper electrode.
- The optimized input parameters for MRR on composite specimens were a maximum level of current (8 amps), a minimum level of pulse-interval (T_{off}) (40 µs), and a high level of pulse-duration (T_{on}) (300 µs), and the contribution percentages of current, pulse-duration (T_{on}), and pulse-interval (T_{off}) on MRR were 41.94, 23.18, and 34.8%, respectively.
- The optimized EDM input parameters combination for TWR was a minimum level of current (4 amps), a low level of pulse-duration (T_{on}) (100 µs), and a maximum level of pulse-interval (T_{off}) (40 µs), and the subsequent contribution percentage of current, pulse-duration (T_{on}) and pulse-interval (T_{off}) on TWR was 55.85%, 29.68%, and 14.43%, respectively.
- The maximum level current and minimum level of pulse-duration (T_{on}) which produce maximum metal removal rate of 35.2 (mm3/min) and high level of pulse-interval (T_{off}) with low level of current and pulse-duration (T_{on}) reduce the Tool wear rate of 0.44 (mg/min).

REFERENCES

1. Egbo MK. A fundamental review on composite materials and some of their applications in biomedical engineering. *J King Saud Univ Eng Sci*. 2021; 33:557–68.
2. Ujah CO, Kallon DV Von. Trends in Aluminium Matrix Composite Development. *Crystals (Basel)*. 2022; 12:1357.
3. Altenbach H, Altenbach J, Kissing W. Classification of Composite Materials. In: *Mechanics of Composite Structural Elements*. Berlin, Heidelberg: Springer; 2004. p. 1–14.
4. Georgantzia E, Gkantou M, Kamaris GS. Aluminium alloys as structural material: A review of research. *Eng Struct*. 2021; 227:111372.
5. Wazeer A, Mukherjee A, Das A, Sengupta B, Mandal G, Sinha A. Mechanical Properties of Aluminium Metal Matrix Composites: Advancements, Opportunities and Perspective. 2024. p. 145–60.
6. Singh B, Kumar I, Saxena KK, Mohammed KA, Ijaz Khan M, Ben Moussa S, et al. A future prospects and current scenario of aluminium metal matrix composites characteristics. *Alexandria Eng J*. 2023; 76:1–17.
7. Shanmugavel R, Chinthakndi N, Selvam M, Madasamy N, Shanmugakani SK, Nair A, et al. Al-Mg-MoS2 Reinforced Metal Matrix Composites: Machinability Characteristics. *Materials*. 2022.
8. Ravi Kumar K, Kiran K, Sreebalaji VS. Micro structural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide. *J Alloys Compd*. 2017; 723:795–801.
9. Kannan C, Ramanujam R, Balan ASS. Machinability studies on Al 7075/BN/Al2O3 squeeze cast hybrid nanocomposite under different machining environments. *Mater Manuf Process*. 2018; 33:587–95.

10. Xavior MA, Kumar JPA. Machinability of Hybrid Metal Matrix Composite - A Review. In: *Procedia Eng*. Elsevier; 2017. p. 1110–8.
11. Han C-S, Vaishnav V, Praveen Kumar R, Chenrayan V. Influence of nano MoS2 particle on the mechanical and tribological properties of Al-TiB2-Gr hybrid composite. *J Mech Sci Technol*. 2022.
12. Rajkumar S, Maridurai T, Mageshkumar K, Ravichandran M, Mohanavel V, Velmurugan P, et al. Experimental investigations on properties of MoS2 and TiB2 reinforced aluminium composites. *Mater Today Proc*. 2022; 59:1301–4.
13. Selvam JDR, Dinaharan I, Rai RS. Matrix and Reinforcement Materials for Metal Matrix Composites. In: *Encyclopedia of Materials: Composites*. Elsevier; 2021. p. 615–39.
14. Zhang C, Jia L, Zhang J, Pan W, Lu Z, Xing Z. Stability of reinforcements (CrB2/TiB2) and lubricants (C/MoS2) in Cu matrix during the sintering process. *J Mater Res Technol*. 2025; 34:2225–31.
15. Garg P, Jamwal A, Kumar D, Sadasivuni KK, Hussain CM, Gupta P. Advance research progresses in aluminium matrix composites: manufacturing & applications. *J Mater Res Technol*. 2019; 8:4924–39.
16. Seetharaman S, Gupta M. Fundamentals of Metal Matrix Composites. In: *Encyclopedia of Materials: Composites*. Elsevier; 2021. p. 11–29.
17. Sharma AK, Bhandari R, Aherwar A, Pinca-Bretotean C. A study of fabrication methods of aluminum based composites focused on stir casting process. In: *Mater Today Proc*. Elsevier; 2020. p. 1608–12.
18. Mohankumar V, Kumarasamy SP, Palanisamy S, Kuriakose Mani A, Durairaj TK, Sillanpää M, et al. Process parameters optimization of EDM for hybrid aluminum MMC using hybrid optimization technique. *Heliyon*. 2024.
19. Rajmohan T, Prabhu R, Rao GS, Palanikumar K. Optimization of Machining Parameters in Electrical Discharge Machining (EDM) of 304 Stainless Steel. *Procedia Eng*. 2012; 38:1030–6.
20. Venkatesh R, Vignesh Kumar M, Kantharaj I, David R, de Poures MV, Hossain I, et al. Improvement of mechanical performance on zirconium dioxide nanoparticle synthesized magnesium alloy nano composite. *Heliyon*. 2024;10(9).
21. Kalil Rahiman M, Vellaichamy R, Nagaraj T, Mathalai Sundaram C, Radha Krishnan B. Optimization of process parameter in Electrical Discharge Machining process via Taguchi method. *Mater Today Proc*. 2022; 69:1351–4.
22. Stalin B, Ravichandran M, Sudha GT, Karthick A, Prakash KS, Asirdason AB, et al. Effect of titanium diboride ceramic particles on mechanical and wear behaviour of Cu-10 wt% W alloy composites processed by P/M route. *Vacuum*. 2021.
23. Ramesh S, Govindaraju N, Suryanarayan CP. Investigation on Mechanical and Fatigue behaviour of Aluminium Based SiC/ZrO2 Particle Reinforced MMC. *IOP Conf Ser Mater Sci Eng*. 2018.
24. Mahajan R, Krishna H, Singh AK, Ghadai RK. A Review on Copper and its alloys used as electrode in EDM. *IOP Conf Ser Mater Sci Eng*. 2018.

