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Comparing the Zinc-coated Brass and Brass Wire for Material Removal Rate in Wire Electrical Discharge Machining Al6061/SiC/Graphite Composite

M. Hiteshkumar and A. Muniappan*

Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

***Correspondence to:**
A. Muniappan
Department of Mechanical Engineering,
Saveetha School of Engineering,
Saveetha Institute of Medical and
Technical Sciences,
Saveetha University,
Chennai, Tamil Nadu, India.
E-mail: muniappan@saveetha.com

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Abstract

This study aims to determine the performance of brass coated wire on novel hybrid aluminum metal matrix composites (MMCs) using Wire Electric Discharge Machine (WEDM). To fabricate the hybrid aluminum-based hybrid MMCs, aluminum AA6061 were selected as a base material, while Graphite (Gr) and Silicon Carbide (SiC) were used as reinforcement materials. Brass wire with a protective coating was used by the experimental group, while brass wire alone was used by the control group. The specimen was fabricated using a stir casting process, and its phase composition was 92% Al6061, 5% SiC, and 3% Gr. A total of 34 samples were selected for the study and 17 samples from each group were used to evaluate the shear strength of MMCs. Compared to the uncoated brass wire, the zinc coated brass wire has a wider kerf as shown by a significant value of 0.000 < 0.05 with a 95% confidence interval. There is a significant difference between the two groups. The maximum material removal rate (MRR) of 134 mg/min was achieved by a zinc wire-coated electrode. Similar studies were carried out on a hybrid composite made of 92% Al6061/5% SiC, and 3% Gr to validate the proposed method. The effect of each machining parameter was investigated using analysis of variance and confirmatory tests. It was discovered that the rate of material removal increased with an increase in pulse-on time and pulse current but decreased with an increase in voltage.

Keywords

Surface roughness, Novel composite, Stir casting, Hybrid composite, Brass wire, Wire Electric Discharge Machine

Introduction

In the last 20 years, hybrid MMCs have been in increasing demand due to its physical and mechanical properties that differ from conventional materials [1]. MMCs include high thermal strength, low density, tensile stiffness, strong temperature resistance, and improved strength ratio that distinguish them from other comparable materials within the same classification. MMCs are a feasible replacement for cast iron which is commonly used in the automotive industry in the manufacture of engines and brakes [2]. The production of aluminum MMCs was primarily accomplished by addison a reinforcement during the stir-casting process in most previous research [3].

The optimization EDM machining parameters of AA6061/SiC/B4C hybrid composite analysis was carried out by [4]. The parent material AA6061 reinforced with 1.5% SiC and 1.5% B4C. Response Surface Methodology (RSM) was employed in this investigation for optimizing machining parameters. The Al-B4C composites were studied by Improve MRR and surface roughness. The input variables considered are wire strain, percentage of reinforcement, pulse on-time and pulse-of-time. There is very little work on wire EDM in composites, even though there is a ton of room for exploration in this area. It should have been determined that wire tension did not make a significant difference in any of the output characteristics [5] developed the wolf pack algorithm to find the best option for wire EDM production of aluminum and SiC composites after using Gaussian regression. The investigation used pulse length, pulse intervals, water pressure and gap voltage as input variables to identify variations in the output responses, namely metal removal rates and 3D surface properties. EDM production of wires of Al/ZrO_2 alloy with metal matrix was improved. He used various optimization techniques to determine the best combinations of input parameters [6]. This investigation, a novel metal hybrid aluminum composite was developed using stir casting, one of the most efficient and low cost-effective casting fabrication techniques. An innovative hybrid aluminum metal matrix material using Al6061 as the base material has not been sufficiently studied using Gr and Sic hard ceramic components as reinforcements. Also, pulse-on time (Ton), Peak current (I), and voltage (V), and tool material were the EDM characteristics that were taken into consideration in this study (EDM electrodes). In the developed Al6061/SiC/Gr hybrid composite, MRR and EDM parameters were evaluated to improve the performance of the fabricated composites. An analysis of variance (ANOVA), regression analysis, and sample t-test was used evaluate the performance of EDM machining parameters by using SPSS software. As a result, the workability of an alloy is different from that of other metals. In conclusion, this research will significantly contribute to determining all the contributing aspects that can affect how a composite material is ultimately machined.

Materials and Methods

A stir casting method was used to make the aluminum hybrid alloy AA6061/SiC/graphite, and the wire EDM experiment was located at Saveetha University. A notable class of innovative engineered materials is aluminum alloy metal matrix composite materials [7]. In this investigation, the specified two reinforcing elements were combined with the raw material (Al6061) 92% at a weight percentage ratio of 5% (SiC) and 3% (Gr), respectively, to form a novel hybrid aluminum matrix composite. The nanoparticles used were SiC and Gr, both of which had a 200-mesh size (average size 75 m). The method of stir casting has been used to produce the hybrid aluminum metal matrix composite, due to its convenience and low development cost [8]. After cooling the liquid was concentrated in the mold to form the final sample. Whenever aluminum material changes its molten state, it is burned to 8500 °C. The molten metal is then allowed to cool while being churned 700 times per minute. Under continuous stirring, the reinforcement (SiC and B4C) was gradually incorporated into the molten metal (Figure 1) [9].

The EDM control variables of material, current (I), voltages (V), and pulse on time (T) were selected. These EDM process variables were selected based on existing findings. Considering group 1 and group 2, brass and zinc-coated wires were selected respectively. Pilot research examined the effects

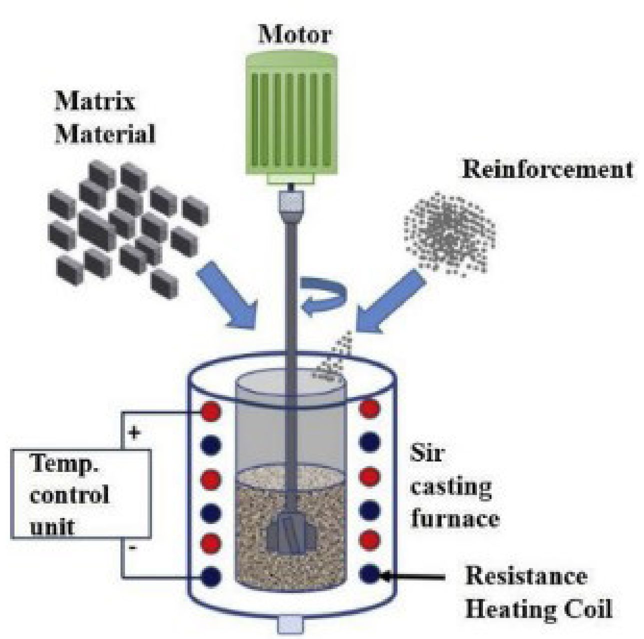

Figure 1: Stir casting setup.

of various concentrations of processing parameters on MRR output responses to determine the most critical values of selected process parameters.

There were 17 slots bored into each specimen at varied spacings. The hybrid composites of wire EDM machining using 0.25 mm for brass wire and zinc-coated wire were used in the experiment, respectively. The sampling size was determined using the ClinCalc tool, considering a pre-test G power of 80% and 5%, CI of 95%. The average and standard deviation from earlier literature was used for quantitative calculations (Tables 1 to table 3, figure 2).

Statistical Analysis

SPSS was used to conduct the statistical analysis to determine the MRR of lightweight materials containing Al6061 alloys. ANOVA was used to establish significance (0.5) between two different groups. Using an approved statistical method (AA6061/SiC/graphite), the shear force values of group 1 brass-coated wire and group 2 zinc-coated wire were compared.

Results

Achieving the ideal MRR was the primary focus of the study. As a result, MRR and used with high-optimal features. Table 4 shows the mean, as well as the variations in MRR by varying selected EDM process parameters. These experiments were carried out three times to verify the results. Similarly, the MRR measurement results of three measurements were taken of the machined surfaces in various places. Figure 3 shows the material removal rate main effect plots of AA6061/SiC/graphite, with an average accuracy of detection of ± 1 SD (X-axis: cutting speed of brass-coated wire (group 1) and zinc-coated wire (group 2)). Figure 3 clearly shows that each of the EDM parameters has a significant impact on the MRR. Here, as shown in table 5, the highest-best parameters

Table 1: Mechanical properties of matrix alloy AA-6061.

Material properties	Value
Modulus of elasticity (GPa)	68.9
Thermal conductivity (W/m-K)	167
Tensile strength (MPa)	310
Density(g/cm³)	2.70

Table 2: AA6061 chemical properties.

Chemical	Percentage
Si	0.483
Mn	0.687
Zn	0.211
Cr	0.013
Ni	0.024
Ti	0.028
Pb	0.02
Fe	0.648
Cu	0.082
Mg	0.077
B	0.002
V	0.007
Al	Balance

Table 3: Thermal and mechanical properties of SiC.

Properties	Value
Melting point	2730 °C
Density	3.22 g/cm³
Poisson's ratio	0.35
Tensile strength	0.1379 GPa
Yield strength	21 GPa
Elongation	6%
Thermal conductivity	120 W/m-K
Modulus of elasticity	90 GPa

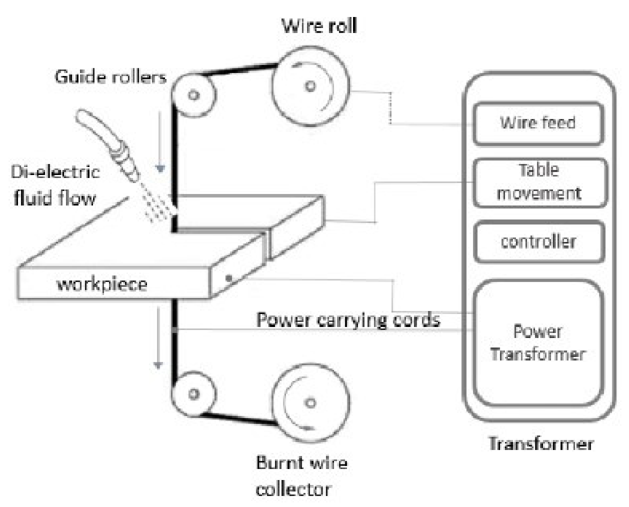

Figure 2: Wire EDM.

were used to analyze the MRR values using ANOVA. Table 6 to table 8 shows the independent test and t-test for the MRR of aluminum with SiC and graphite reinforced composites.

Table 4: Process parameter used in the experiments.

Parameters	Values
Current (A)	10, 15, and 20
Pulse on time (µm)	80, 100, and 120
Wire feed rate (m/min)	6, 8, and 10

Figure 3: Mean kerf-width of AA6061/SiC/graphite with mean accuracy of detection ± 1 SD. X axis: Kerf width of brass coated wire (group 1) and zinc coated wire (group 2).

Table 5: Group statistics obtained for cutting speed of brass coated wire (Group 1) and zinc coated wire (Group 2).

Group statistics					
	Group	N	Mean	Std. deviation	Std. error mean
Cutting speed	Brass wire CG	17	9.942706	0.1621079	0.0393169
	Zinc wire EG	17	10.897335	0.4037445	0.0979224

Discussions

The results clearly show that hybrid composites of MRR increase with increases in high current and pulse of duration. MRR with higher discharge energy may result from higher spark energy. A significantly larger dielectric strength of the copper electrode leads to a larger MRR. The improved the workpiece behavior in Al6061/SiC/Gr composites during fabrication, leading to significant MRR. However, current has not proven to be a suitable EDM parameter in terms of its effect on MRR [10-12] examined the WEDM process variables on aluminum 6061 composites with varying percentage reinforcement of SiC and B4C [13-15]. Three samples were prepared for the studies. Input parameters such as current, pulse-on-time, pulse-off time, and gap voltages were properly considered. The surface roughness for Al6061-3% SiC was found to be affected by voltage, whereas the MRR was affected by pulse time. Both results are verified by the ANOVA method. It was found that voltage plays an important role in regulating the output characteristics for Al6061-7% SiCp-3% B4C. The same trend was observed for the current investigation of AA6061/SiC/Gr composites [16, 17]. The effects of WEDM method variables on the cutting speed of the prepared composite were studied using a one-sample t-test and panel statistics. The observed conclusions and experimental

Table 8: Independent sample test statistics obtained for MRR of brass coated wire (group 1) and zinc coated wire (group 2).

t-test for equality of means					
	Group	**Sig (2 tailed)**	**Mean difference**	**Std error difference**	**95% confidence level**
MRR	Equal variance assumed	0.1055207	-1.1695681	-0.7396907	0.0093779
	Equal variance assumed	0.1055207	-1.1740539	-0.7352049	0.0095060

Table 6: MRR of AA6061/SiC/graphite and zinc coated wire group 1 and brass coated wire group 2.

Specimen ID	**MRR mg/min**	
	Zinc coated wire group 1	**Brass coated wire group 2**
Sample 1	60.24	58.26
Sample 2	62.34	61.32
Sample 3	67.16	65.28
Sample 4	75.31	74.31
Sample 5	84.69	80.61
Sample 6	88.29	85.24
Sample 7	96.52	92.67
Sample 8	108.32	104.26
Sample 9	112.63	109.58
Sample 10	114.85	112.35
Sample 11	118.94	114.26
Sample 12	120.34	118.62
Sample 13	123.63	120.32
Sample 14	126.52	122.34
Sample 15	128.39	124.26
Sample 16	132.34	128.32
Sample 17	134.26	130.57

Table 7: Independent sample test Statistics obtained for MRR of brass coated wire (group 1) and zinc coated wire (group 2).

Independent sample test					
	Group	**F**	**Sig**	**t**	**df**
MRR	Equal variance assumed	4.559	0.41	-9.047	28
	Equal variance assumed	0	-	-9.047	16.576

findings are well in line with earlier studies.

Conclusion

In this study, electrical discharge machining is experimentally investigated with respect to the recently discovered metal matrix composite. This is made using the stir-casting technique. A statistical strategy was used to confirm the contribution of each selected electrical discharge machine parameter (voltage, pulse-on time, and peak current). With the increase of current and duration of pulses, the MRR of the novel aluminum metal matrix composite rises from 40% to 50%, while it decreases by 20% with the increase of voltage. In addition, a copper electrode is more effective at removing material at a higher rate than a brass electrode from the newly formulated Al6061 (92%)/SiC (5%)/Gr (3%) alloy. The obtained results of the MRR value of electrodes coated with zinc and brass wire are in good agreement with the results of the investigation.

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None.

Conflict of Interest

None.

References

1. Bains PS, Sidhu SS, Payal HS, Kaur S. 2019. Magnetic field influence on surface modifications in powder mixed EDM. *Silicon* 11(1): 415-423. https://doi.org/10.1007/s12633-018-9907-z
2. Bodunrin MO, Alaneme KK, Chown LH. 2015. Aluminium matrix hybrid composites: a review of reinforcement philosophies; mechanical, corrosion and tribological characteristics. *J Mater Res Technol* 4(4): 434-445. https://doi.org/10.1016/j.jmrt.2015.05.003
3. Das S, Chandrasekaran M, Samanta S. 2021. Study on mechanical properties of AA6061/SiC/B_4C hybrid nano metal matrix composites. Mater Sci Forum 1034: 35-42. https://doi.org/10.4028/www.scientific.net/MSF.1034.35
4. Ekici E, Motorcu AR, Kuş A. 2016. Evaluation of surface roughness and material removal rate in the wire electrical discharge machining of Al/B_4C composites via the Taguchi method. *J Compos Mater* 50(18): 2575-2586. https://doi.org/10.1177/0021998315609788
5. Garg SK, Manna A, Jain A. 2022. Investigation and analysis of surface veracity and parametric aspects during wire EDM of Al/ZrO_2(p)-metal matrix composite. *Arab J Sci Eng* 47(7): 8417-8438. https://doi.org/10.1007/s13369-021-05531-9
6. James SJ, Venkatesan K, Kuppan P, Ramanujam R. 2014. Hybrid aluminium metal matrix composite reinforced with SiC and TiB2. *Proc Eng* 97: 1018-1026. https://doi.org/10.1016/j.proeng.2014.12.379
7. Sathish T, Kamaraj L, Mohanavel V, Jazaa Y, Qahtani F, et al. 2023. A novel technique implementation to fabricate and analysis of AZ91D with TiN through FSP. *Int J Adv Manuf Technol* 1-6. https://doi.org/10.1007/s00170-023-12024-6
8. Ma J, Ming W, Du J, Huang H, He W, et al. 2018. Integrated optimization model in wire electric discharge machining using Gaussian process regression and wolf pack algorithm approach while machining SiCp/Al composite. *Adv Mech Eng* 10(9): 1687814018787407. https://doi.org/10.1177/1687814018787407
9. Pandi G, Muthusamy S. 2012. A review on machining and tribological behaviors of aluminium hybrid composites. *Proc Eng* 38: 1399-1408. https://doi.org/10.1016/j.proeng.2012.06.174

10. Ramesh S, Natarajan N, Krishnaraj V, Kumar KS. 2014. Investigation on the effect of multi wall carbon nano tubes in wire electrical discharge machining of hybrid metal matrix composites. *Appl Mech Mater* 592: 456-460. https://doi.org/10.4028/www.scientific.net/AMM.592-594.456

11. Sharma P, Sharma S, Khanduja D. 2015. A study on microstructure of aluminium matrix composites. *J Asian Ceram Soc* 3(3): 240-244. https://doi.org/10.1016/j.jascer.2015.04.001

12. Sathish T, Sunagar P, Singh V, Boopathi S, Al-Enizi AM, et al. 2023. Characteristics estimation of natural fibre reinforced plastic composites using deep multi-layer perceptron (MLP) technique. *Chemosphere* 337: 139346. https://doi.org/10.1016/j.chemosphere.2023.139346

13. Sathish T, Maheswari SU, Balaji V, Nirupama P, Panchal H, et al. 2023. Coastal pollution analysis for environmental health and ecological safety using deep learning technique. *Adv Eng Softw* 179: 103441. https://doi.org/10.1016/j.advengsoft.2023.103441

14. Singh M, Garg HK, Maharana S, Yadav A, Singh R, et al. 2021. An experimental investigation on the material removal rate and surface roughness of a hybrid aluminum metal matrix composite (Al6061/sic/gr). *Metals* 11(9): 1449. https://doi.org/10.3390/met11091449

15. Singh PN, Raghukandan K, Pai BC. 2004. Optimization by grey relational analysis of EDM parameters on machining Al–10% SiCP composites. *J Mater Proc Technol* 155: 1658-1661. https://doi.org/10.1016/j.jmatprotec.2004.04.322

16. Thanikodi S, Britto AS, Dattu VS, Al Obaid S, Alfarraj S, et al. 2023. Machining and mechanical characterization of friction stir processed (FSP) surface hybrid composites (AA8014 + TiB2 + ZrO_2). *Int J Adv Manuf Technol* 1-8. https://doi.org/10.1007/s00170-023-12198-z

17. Suresh S, Moorthi NS. 2013. Process development in stir casting and investigation on microstructures and wear behavior of TiB_2 on Al6061 MMC. *Proc Eng* 64: 1183-1190. https://doi.org/10.1016/j.proeng.2013.09.197