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Effect of Dielectric Fluid and Control Parameters During Machining Al7055 and Nano Si_3N_4 Metal Matrix Composites

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Abstract

This paper deals with the electric discharge machining of Al 7055 and nano silicon nitride (Si_3N_4) to find the effect of various input parameters on discharge current, flushing pressure, pulse off time and pulse on time over the response parameters such as material removal rate (MRR), surface roughness (SR) and electrode wear rate (EWR). The metal matrix composite was taken in the combination of Al 7055 with 9% Si_3N_4 of particulate size and a particle size of 30 nm. Taguchi L9 orthogonal array was chosen for analysing and conducting experiments to find the optimum input parameters. Also, Taguchi assisted grey relational analysis (GRA) was used to find the multi-objective input parameters. The result through Taguchi shows that input current and pulse on time is the most influencing parameters on SR, EWR and MRR. The GRA results shows that 5 input of discharge current 40 pulse on time, 20 pulse off time and 0.25 of flushing pressure offers better response results.

Keywords

Electric discharge machining, Al 7055, Silicon nitride, Taguchi, Grey relational analysis, Electrode wear rate

Introduction

The accessibility and use of complicated machinability materials have increased, driven by a rising demand for high strength materials in technically sophisticated industries and encouraged by developments in the field of material science [1, 2]. For the machining of these kinds of materials, unconventional machining techniques are required. One such procedure, known as electrical discharge machining (EDM), is frequently used to machine materials that conduct electricity. A thermoelectric process called EDM in which the process of carefully controlled spark creation, material is removed. It is one of the widely utilized non-traditional machining techniques in industries [3-5]. The material's toughness and strength are unaffected by the EDM process, however compared to machining and turning, it has a lower MRR. The MRR can be increased using several techniques, such as enhancing electrical discharge or on-time discharging pulse. However, using these techniques results in worsening tool wear and surface finish [6]. The Taguchi approach was used to optimize the EDM process parameters for milling the RENE80 nickel super alloy material with aluminum as the electrode material. It was found that the input current responded significantly for increasing in MRR and decrease in tool wear rate (TWR), and SR [7]. The impact of input parameters on EDM of MDN 250 steel is investigated. They have recognized discharge current, pulse on time, and duty cycle as performance indicators whereas processing parameters are MRR and SR. Although, parametric optimization was not carried out in their investigation.

TWR and RWR ratios were not considered. Additionally, they had conducted additional research and created a hybrid approach for SR to forecast how the MDN 250 steel will behave after machining process [8]. An orthogonal array exploratory approach is used to machine Inconel 718, which is taken into consideration as the work piece material. Grey-Taguchi and TOPSIS methods are employed to identify the optimum combination of EDM parameters. For the EDM parameters of current (I), voltage (V), pulse on-time, and enhanced responsiveness, it is discovered that 10 A, 30 V, 200 microns, and 20 microns are the best combinations of input variables by the Grey-Taguchi process. Additionally, the TOPSIS approach is used to determine the optimal parameter setting for the performance measures machined rate, TWR, overcut, and taper overcut [9]. The squeeze casting technology was used to create the prepared samples. On the response variable of MRR, milling timing, and surface finish, pulse on time, pulse off time, and gap voltage. According to the outcomes of the trials, the best surface smoothness and machining time was attained by utilising a moderate level pulse on time, a greater level pulse duration, and a lower gap voltage. MRR was attained by using a moderate voltage, a relatively short pulse on time, and a long pulse off time [10]. The matrix AA2024–nano silicon dioxide was selected in different weight percentages. The composites were developed by stir casting method. The researcher investigated that by adding silicon dioxide there is decrease in MRR and increase in TWR at 2 wt.% and decrements in TWR at 3 wt.% [11]. AA7075–Si_3N_4 reinforced composites were synthesized by stir casting technique. He selected three input parameters like current, pulse on time, wire feed. He concluded that pulse on time, current was the most influential parameter in achieving good MRR and better surface finish [12]. The machining studies were conducted on developed composites. An L18 orthogonal array technique were employed by varying the input parameters. The comparison was done between nickel coated electrode and uncoated brass electrode and their impact on MRR. From experimentation, the results reveals that there is increase in MRR for nickel coated electrode as compared to uncoated brass electrode. The electrode material is the influencing factor which increases MRR and minimizes EWR [13]. Machinability studies were conducted on Al 6063 hybrid composites. The composites were fabricated through stir casting method by varying weight percentages of boron carbide and zirconium orthosilicate. Depth of cut, MRR was increased, and surface finish was decreased. The scanning electron microscope analysis results reveal that there is occurrence from ductile to brittle fracture [14].

Experimentation

The EDM SPARKONIX MOS 25A made for this research had a motor as well as a good polarity electrode as shown in figure 1 and the specimen to be machined also shown in figure 1. EDM 20 oil of economic quality for draining on inner wall and flanks. When the component was removed and from the setup and the roughness of the surface is weighed and measured. The outside Mitutoyo roughness tester was used to measure the SR of the component. Also, the MRR was measured by using a micro weigh scale by before and after machining process.

Material

The main component of the exotic alloys Al 7055. Under typical conditions, it is ductile, somewhat soft, and simple to work with It is possible to roll, forge, and extrude the alloy to create a variety of shapes and goods. Al 7055 has a higher tensile strength than aluminum, however it has low corrosion resistance. It contains 2% Cu, 2.1% Mg, 0.9% Mn, 0.5% Fe, 0.14% Si, 7.8% Zn, 0.14%, 0.25% Zr, 0.10% Ti. Si_3N_4 is chosen as a primary reinforcement with a particle size of 30 nm and 9% of Si_3N_4, it is a ceramic compound. It is extremely hard and corrosion resistant. The sample material was prepared and milled into a dimension of 75 x 75 mm.

Experimental design

Taguchi method was adapted to design the experiment in this EDM process. Four parameters such as discharge current, pulse on time, pulse off time and flushing pressure with three levels. Taguchi L9 orthogonal array was chosen for conducting the experiments as shown in table 1. During each experiment, the work piece and electrode was washed, dried, and weighted to determine the MRR and EWR. Measuring was done using

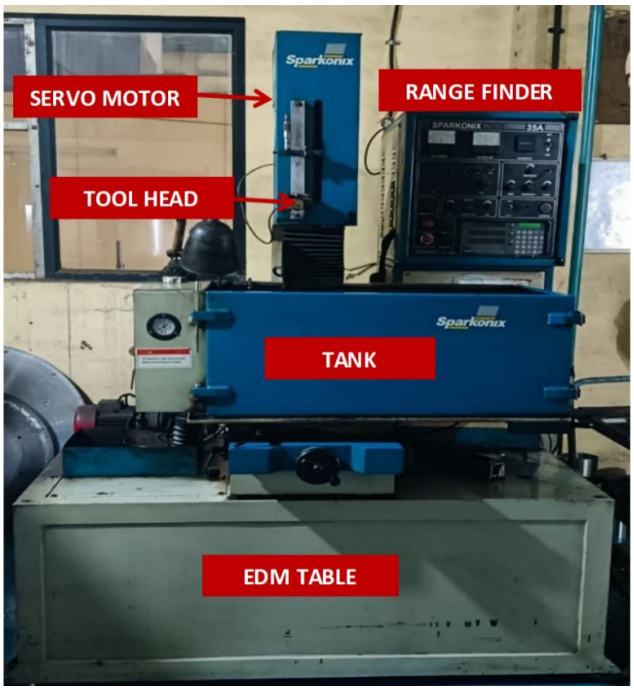


Figure 1: SPARKONIX MOS 25A die sinking setup.

Table 1: Machining parameters and levels.

Machining parameter	Symbol	Unit	Level 1	Level 2	Level 3
Discharge current	I_p	amps	5	10	15
Pulse on time	T_{on}	µs	40	50	120
Pulse off time	T_{off}	µs	20	30	40
Flushing pressure	F_p	kg/cm^2	0.25	0.50	0.75

an automated weighing scale from CONTECH with a 150 g capacity and 0.0001 accuracy. The experimental results of EWR, SR, and MRR are shown in table 2. Figure 2 shows the electrode image in a dielectric medium i.e., kerosene enriched with servo therm oil and nano powder of Si_3N_4.

Results and Discussion

The results of signal to noise (SN) ratio for MRR are shown in figure 3. The discharge current and pulse on time is the most influencing parameter which affects MRR. At 15 A of discharge current, 120 µs of pulse on time, 40 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers increase in MRR. The side-cutting that occurs along the tool's cylindrical face is what causes this phenomenon for increase in MRR this is due to increase in pulse on time [15]. While machining is being done. More of the tool enters the work piece while it is being machined, and the length that side-cutting occurs over lengthens the cutting tool [16]. The above combination offers higher MRR in machining of metal matrix composites.

Figure 4 shows that at 5 A of discharge current, 40 µs of pulse on time, 40 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers lowering in EWR. It was discovered that after EDM process, some waste materials were formed on the tool surface. The constant value of EWR may be explained by this material deposition on the tool electrode. Large amounts of debris are produced, and more material is accumulated on the electrode at high MRR circumstances [17]. Since the differential in tool weight between before and after processing is used to determine EWR, the combined impact of coating and remove from the tool is considered when calculating EWR. The time constant of EWR implies that even if process variables are altered, the differential between waste collected from and materials deposited on the tool surface [18].

At 5 A of discharge current, 40 µs of pulse on time, 20 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers decreases SR of machined surface. SR values tend to decline as voltage rises, which may indicate that larger although deeper craters occur at greater voltage levels. Discharge occurs when the dielectric toughness is exceeded by the effective electromagnetic current between electrodes medium [19]. Consequently, the discharging spacing increases as the gap voltage increases, and even at higher temperatures the breakup electric field can then be produced. a gap's width. When there is less effective gas velocity at the work piece surface (Figure 5 and table 3).

Figure 6 shows that the overall combination of the process parameter for improvising the MRR and for lowering the TWR and SR from the figure it could be identified that it

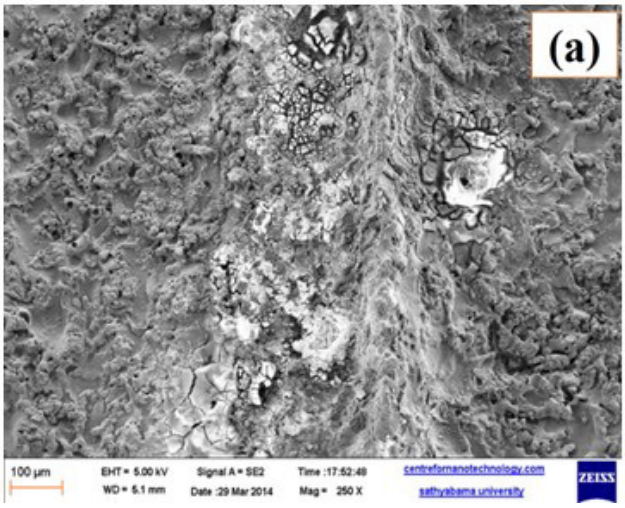


Figure 2: Kerosene + Servo therm oil + Nano Si_3N_4.

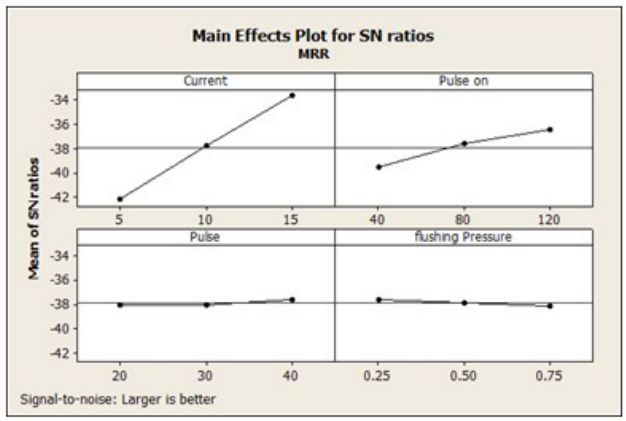


Figure 3: SN ratio for MRR.

Table 2: Design of experiments with response parameters.

S. No.	Current	Pulse on	Pulse off	Flushing pressure	MRR	EWR	SR
1	5	40	20	0.25	0.0062	0.0005	3.3859
2	5	80	30	0.5	0.0083	0.0007	4.5479
3	5	120	40	0.75	0.0091	0.0011	5.4964
4	10	40	30	0.75	0.0102	0.0018	5.2546
5	10	80	40	0.5	0.0135	0.0023	5.8482
6	10	120	20	0.25	0.0157	0.0026	6.3015
7	15	40	40	0.5	0.0187	0.0032	6.0047
8	15	80	20	0.75	0.0204	0.0034	7.7556
9	15	120	30	0.25	0.0234	0.0037	8.332

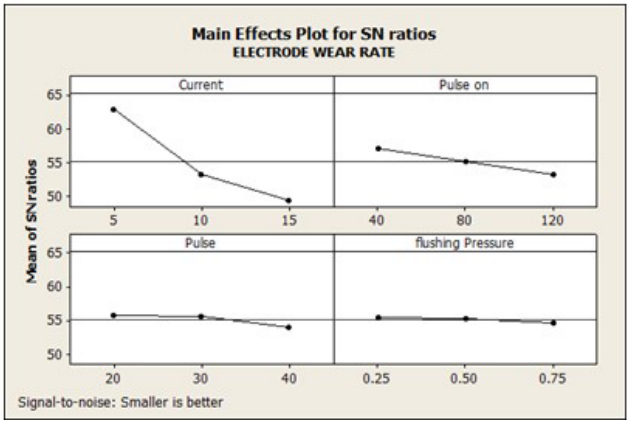


Figure 4: SN ratio for EWR.

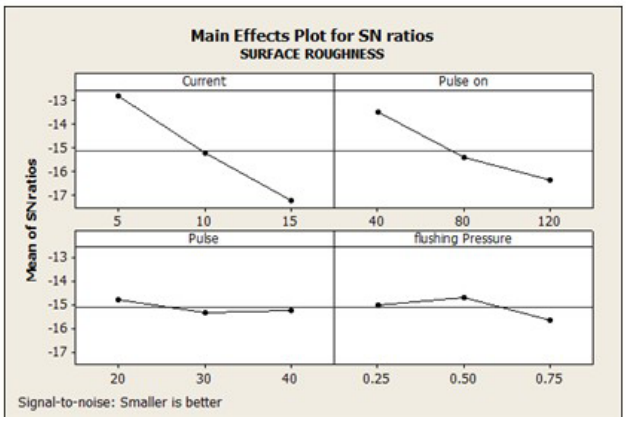


Figure 5: SN ratio for SR.

the input current and pulse on time is the most influencing parameter for increase in MRR and surface finish. 5 A of discharge current, 40 µs of pulse on time, 40 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers lowering in EWR, SR and increasing in MRR.

Conclusion

In this experiment EDM of Al 7055 and nano Si_3N_4 to find the effect of various input parameters on discharge current, flushing pressure, pulse off time and pulse on time was analyzed using Taguchi assisted GRA. The results shows that at 15 A of discharge current, 120 µs of pulse on time, 40 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers increase in MRR, at 5 A of discharge current, 40 µs of pulse on time, 40 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers lowering in EWR and 40 µs of pulse on time, 20 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers decreases SR, also the GRA results revels that 5 A of discharge current, 40 µs of pulse on time, 40 µs of pulse off time and 0.25 kg/cm^2 of flushing pressure with offers lowering in EWR, SR and increasing in MRR.

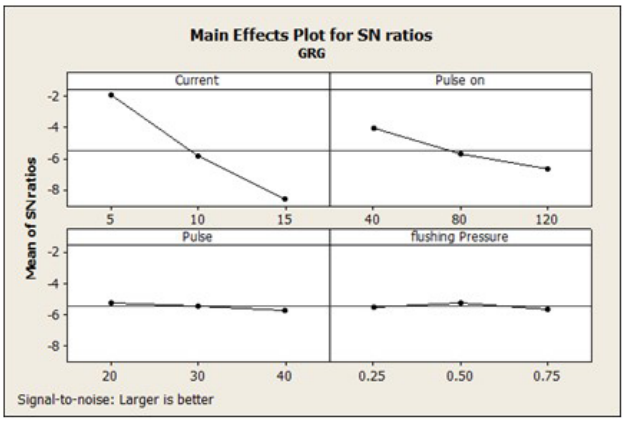


Figure 6: SN ratio for GRG.

Acknowledgments

None.

Conflict of Interest

None.

References

1. M'Saoubi R, Axinte D, Soo SL, Nobel C, Attia H, et al. 2015. High performance cutting of advanced aerospace alloys and composite materials. *CIRP Annals* 64(2): 557-580. https://doi.org/10.1016/j.cirp.2015.05.002
2. Gouda D, Panda A, Nanda BK, Kumar R, Sahoo AK, et al. 2021. Recently evaluated electrical discharge machining (EDM) process performances: a research perspective. *Mater Today Proc* 44: 2087-2092. https://doi.org/10.1016/j.matpr.2020.12.180

Table 3: Normalization and coefficient of friction of response parameters.

MRR	EWR	Mean (SR)	Nor MRR	Nor EWR	Nor SR	Coeff MRR	Coeff EWR	Coeff SR	GRG
0.0062	0.0005	3.3859	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.0083	0.0007	4.5479	0.8343	0.9375	0.7651	0.7510	0.8889	0.6803	0.7734
0.0091	0.0011	5.4964	0.7901	0.8125	0.5733	0.7043	0.7273	0.5395	0.6570
0.0102	0.0018	5.2546	0.7293	0.5938	0.6222	0.6487	0.5517	0.5696	0.5900
0.0135	0.0023	5.8482	0.5470	0.4375	0.5022	0.5246	0.4706	0.5011	0.4988
0.0157	0.0026	6.3015	0.4254	0.3438	0.4105	0.4653	0.4324	0.4589	0.4522
0.0187	0.0032	6.0047	0.2597	0.1563	0.4705	0.4031	0.3721	0.4857	0.4203
0.0204	0.0034	7.7556	0.1657	0.0938	0.1165	0.3747	0.3556	0.3614	0.3639
0.0234	0.0037	8.332	0.0000	0.0000	0.0000	0.3333	0.3333	0.3333	0.3333

3. Pradhan BB, Masanta M, Sarkar BR, Bhattacharyya B. 2009. Investigation of electro-discharge micro-machining of titanium super alloy. *Int J Adv Manuf Technol* 41: 1094-1106. https://doi.org/10.1007/s00170-008-1561-y
4. Joshi AY, Joshi AY. 2019. A systematic review on powder mixed electrical discharge machining. *Heliyon* 5(12): e02963. https://doi.org/10.1016/j.heliyon.2019.e02963
5. Zia MK, Pervaiz S, Anwar S, Samad WA. 2019. Reviewing sustainability interpretation of electrical discharge machining process using triple bottom line approach. *Int J Precis Eng Manuf Green Technol* 6: 931-945. https://doi.org/10.1007/s40684-019-00043-2
6. Wang CC, Yan BH. 2000. Blind-hole drilling of Al_2O_3/6061Al composite using rotary electro-discharge machining. *J Mater Process Technol* 102(1-3): 90-102. https://doi.org/10.1016/S0924-0136(99)00423-9
7. Chandramouli S, Shrinivas Balraj U, Eswaraiah K. 2014. Optimization of electrical discharge machining process parameters using Taguchi method. *Int J Adv Mech Eng* 4(4): 425-434.
8. Rangajanardhaa G. 2009. Development of hybrid model and optimization of surface roughness in electric discharge machining using artificial neural networks and genetic algorithm. *J Mater Process Technol* 209(3): 1512-1520. https://doi.org/10.1016/j.jmatprotec.2008.04.003
9. Yuvaraj T, Suresh P. 2019. Analysis of EDM process parameters on Inconel 718 using the grey-Taguchi and Topsis methods. *J Mech Eng* 65(10): 557-565. https://doi.org/10.5545/sv-jme.2019.6194
10. Hemadri K, Daniel SA, Parthiban A. 2022. Investigation on the response parameters in electric discharge machining of developed aluminium metal matrix composites. *Mater Today Proc* 68: 1214-1218. https://doi.org/10.1016/j.matpr.2022.05.566
11. Kumar V, Singh B, Chandel S, Singhal P. 2020. Evaluation of EDM characteristics of synthesised AA2024-2 & 3 wt% SiO_2 metal matrix nanocomposite (MMNC). *Mater Today Proc* 26: 1449-1454. https://doi.org/10.1016/j.matpr.2020.02.298
12. Raju K, Balakrishnan M, Priya CB, Sivachitra M, Narasimha Rao D. 2022. Parametric optimization of wire electrical discharge machining in AA7075 metal matrix composite. *Adv Mater Sci Eng* 2022: 4438419. https://doi.org/10.1155/2022/4438419
13. Anbuchezhiyan G, Saravanan R, Pugazhenthi R, Palani K, Mamidi VK. 2022. Influence of coated electrode in nanopowder mixed EDM of Al–Zn–Mg–Si_3N_4 composite. *Adv Mater Sci Eng* 2022: 9539790. https://doi.org/10.1155/2022/9539790
14. Thamizhvalavan P, Yuvaraj N, Arivazhagan S. 2022. Abrasive water jet machining of Al6063/B_4C/$ZrSiO_4$ hybrid composites: a study of machinability and surface characterization analysis. *Silicon* 14(3): 1093-1021. https://doi.org/10.1007/s12633-020-00888-2
15. Patel DS, Jain VK, Shrivastava A, Ramkumar J. 2019. Electrochemical micro texturing on flat and curved surfaces: simulation and experiments. *Int J Adv Manufac Technol* 100: 1269-1286. https://doi.org/10.1007/s00170-016-9700-3
16. Shaikh MB, Ali M. 2021. Turning of steels under various cooling and lubrication techniques: a review of literature, sustainability aspects, and future scope. *Eng Res Exp* 3(4): 042001. https://doi.org/10.1088/2631-8695/ac2e10
17. Zhang Z, Zhang Y, Lin L, Wu J, Yu H, et al. 2021. Study on productivity and aerosol emissions of magnetic field-assisted EDM process of SiC_p/Al composite with high volume fractions. *J Clean Prod* 292: 126018. https://doi.org/10.1016/j.jclepro.2021.126018
18. Naik S, Das SR, Dhupal D. 2021. Experimental investigation, predictive modeling, parametric optimization, and cost analysis in electrical discharge machining of Al-SiC metal matrix composite. *Silicon* 13: 1017-1040. https://doi.org/10.1007/s12633-020-00482-6
19. Yousefpour K, Lin W, Wang Y, Park C. 2020. Discharge and ground electrode design considerations for the lightning strike damage tolerance assessment of CFRP matrix composite laminates. *Compos Part B Eng* 198: 108226. https://doi.org/10.1016/j.compositesb.2020.108226