International Journal of Science and Engineering Applications
Volume 10-Issue 05, 76 - 79, 2021, ISSN:- 2319 - 7560

Effect of Maghemite (γ-Fe2O3) Nano-Powder Mixed Dielectric Medium on Material Removal Rate (MRR) During Micro-EDM of AL6061

Nagwa Mejid Ibrahim
Benghazi University, Industrial and Manufacturing System Engineering Benghazi, Libya

Zienab B. Mohamed
Benghazi University, Industrial and Manufacturing System Engineering Benghazi
Libya

Abstract: AL6061 alloys are high-potential materials for many manufacturing sectors including automobiles, aerospace, electrical, military, sports and engineering components, owing to their better technological properties. Through the thermal erosion process of Electrical Discharge Machining (EDM), an electrically-produced spark vaporizes materials that are electrically conductive. This study examines the viability of improvement of material removal rate in the micro-electric discharge machining of AL6061 alloy using Fe_2O_3 nano-powder-mixed dielectric fluid. For the purpose of this research, a copper electrode with 500µm diameter and positive polarity was used. The performance measures of the machining process were investigated regarding the material removal rate (MRR). one concentration of nano-powder were added to dielectric (4g/l). Results showed that if Iron oxide nano-powders (Fe_2O_3) exists in the dielectric, MRR can be significantly improved.

Keywords: Powder-mixed Micro -EDM, Fe_2O_3 nano-powder, Material removal rate **(MRR).**

1. INTRODUCTION

process currently applied to the production of various tools and molding industries is electrical discharge machining (EDM) that can be properly used for machining of electrically-conductive parts and also this method is capable of generating complex shapes with no limitation in the material hardness [1]. One of the most proficient modern machining processes regarding the size and the precision of products is Micro-EDM, which out performs other fabrication processes like a laser, LIGA, ultrasonic ion beam, and so on. [2]. Micro-EDM (µEDM) is broadly applied to the field of micro-mould making and the generation of dies, cavities, and complex 3D structures [3]. In the technologies of EDM/µEDM, one of the latest advancements is powder-mixed electric discharge machining (PMEDM) that works with the addition of powder particles to dielectric for improving machining rate. Suspended particles cause a reduction in the dielectric overall electrical resistivity, and they allow sparking to occur from a larger distance. Flushing conditions and the improved spark frequency together with multiple sparks lead to the simultaneous improvement of material removal rate [4]. AL6061 alloy is widely used in dies and moulds industry. The 6000 series aluminum have many alloys with different names and properties. Al 6061 alloy is one of the most extensively used of these series [5].

Various researchers have added different powders to dielectric fluids for improving the material removal rate**.** The investigation of (Jahan, M P et., al 2010) employed nano-powders of graphite, Al, and Al_2O_3 for PMµEDM of WC10%Co alloy [6]. The authors reported no significant effect was found with Al_2O_3 while Al and graphite powders significantly improved MRR and surface quality. The study by (Assarzadeh and Ghoreishi, 2012) investigated the effect of electrical and non-electrical process parameters on MRR and SR during PMEDM of CK45 alloy. The selected dielectric additives used were Al_2O_3, Cu, and SiC. The experiments were conducted using RSM design whereas optimization was determined using the desirability approach [7]. (Kansal *et al.*, 2007) found that The suspension of silicon powder into the dielectric fluid of EDM appreciably enhances material removal rate [8]. In a separate study (Jahan *et al.*, 2011) investigated the feasibility of improving the surface characteristics of cemented tungsten carbide (WC–Co)– die and mould material during micro-EDM. Comparative performance analysis of powder-mixed sinking and milling micro-EDM has been examined. It was observed that semi-conductive nano-size graphite powder in the dielectric significantly improved surface finish, MRR and reduced EWR [9]. In addition, according to (NM elsiti *et a*l., 2017) MRR can be significantly improved when Fe_2O_3 nano powder was added to dielectric fluid during micro-EDM of Co-Cr- Mo [10].

2. EXPERIMENTAL DETAILS

The experiments in the present research were conducted on an AG40L Sodick electrical discharge machine (see Fig.2). Copper electrodes with a diameter of 500μm were selected and utilized as tool material. This is due to its low cost, good machinability, and fine surface finish potentials**.** The commercially available "EDM 23" oil was selected as the dielectric fluid in this study**.** The weights of the electrodes and workpiece(s) were measured using the Precision Balance (Model: Pioneer™) before and after each micro-EDM process. This is a digital weighing scale capable of obtaining 0.0001-g precision and maximum weights of 200 g. The results of the Micro-EDM of AL6061 was planned and analyzed using Design of Experiments (DoE) software, Design-Expert *version* 7. The maghimite nano-particles (γ-Fe_2O_3) with size <10 nm, were added to the dielectric fluid in concentration (4g/l). The powder mixed EDM experiments were conducted in an in-house designed machining tank with dimensions; 46 cm × 35 cm × 24 cm. The tank was fabricated with 1.5 mm thick stainless steel sheets as shown in Figure 3.22. The selected process parameters were; peak current (A), voltage (B), and pulse-on time (C). The measured response was MRR. Table 3.9 illustrates the experimental plan and design.

Table 1. Experimental plan and design

Exp no	A (Current) (Ip)	B (Voltage) (V)	C (Pulse on) (µs)
1	1.5	60	10
2	3	60	10
3	1.5	120	10
4	3	120	10
5	1.5	60	200
6	3	60	200
7	1.5	120	200
8	3	120	200
9	2.25	90	105
10	2.25	90	105
11	2.25	90	105

The MMR is calculated from the mathematical expression in Eq 1;
$MRR = [(W1-W2)/(t \times \rho)] \times 1000 \quad (mm^3/min)$ (1)
The terms $W1$ and $W2$ represent the initial and final weights of the workpiece, respectively. The terms ρ denote the density (g/mm^3) of the workpiece whereas t denotes the machining time (min).

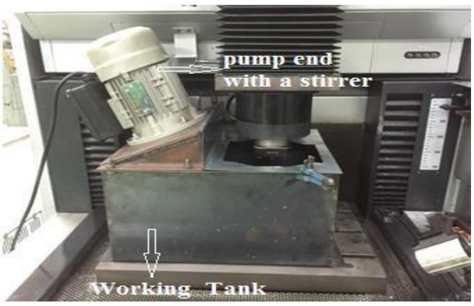

Figure 1. Working Tank

Figure 2. AG40L Sinker EDM

3. RESULTS AND DISCUSSION

As observed from the table 3, the factors A and C significantly influence the Material Removal Rate (MRR1). The results indicate that the interaction between the process parameters peak current and pulse on time is significant for MRR1.The effect plot of the process parameters on MRR 1 are shown in Figures 3. The material removal rate (MMR) during EDM is a function of the electrical discharge energy. In principle, an increase of peak current generates high energy intensity resulting in increased melting of the workpiece material. According to Figure 4, the MRR2 increases with a corresponding increase in gap voltage and current. This is because higher voltage increases the spark gap, thereby improving flushing conditions during the machining process. It is evident from same figure that there is a strong interaction between current and voltage. Pulse on time also had significant effect on MRR2. As observed, the lack of fit had an insignificant effect as expected for the MRR1 and MRR2 responses. As a result, all of the insignificant factors were removed to improve the models. The results for MRR1,2 demonstrated that R-squared value (0.8139,8563), which are ~ 1, is desirable. Hence, there was only a marginal difference (< 0.2) between the Adj. R^2 and Pred. R^2. This indicates a suitable correlation exists between the input and output parameters of the model. Accordingly, the final regression models based on actual prediction factors for MRR1,2 are presented in Eq. 2,3.

MRR1 = 0.053+ 0.028*A- 0.042*C- 0.025*AC (2)
MRR2 = 0.12+ 0.095*A + 0.02*B - 0.041C + 0.033*AB (3)

In addition, findings in figure 7 showed that the addition of 4 g/l of Fe_2O_3 nano-powder to the dielectric fluid increased the MRR. Likewise, the increase in powder concentration from 0 to 4 g/l enhanced the MRR.

Table 2. Experimental plan and results

Exp no	Ip	V	ton	MRR1 Without nanopowder (mm^3/min)	MRR2 4g/l-nanopowder (mm^3/min)
1	1.5	60	10	0.0743027	0.09816
2	3	60	10	0.173766	0.235063
3	1.5	120	10	0.0214707	0.0476361
4	3	120	10	0.132275	0.345598
5	1.5	60	200	0.00643004	0.0186865
6	3	60	200	0.0182997	0.129199
7	1.5	120	200	0.0182516	0.019114
8	3	120	200	0.0203687	0.230719
9	2.25	90	105	0.026936	0.0305747
10	2.25	90	105	0.0124634	0.0733407
11	2.25	90	105	0.0838939	0.0979274

Table 3: Analysis of variance (ANOVA) test for MRR1

Source	Sum of squares	DF	Mean Square	F Value	Prob>F
A-Current	6.28E-	1	6.286E	7.57	0.0285
C-Pulse on	0.014	1	0.014	17.24	0.0043
AC	4.816E	1	4.816E	5.8	0.0469
Residual	5.814E	7	8.306E		
Lack of fit	2.962E	5	5.925E	0.42	0.8147
Core total	0.031	10			
R^2	0.8139	Adj -R^2	0.7341	Pred R^2	0.5909

Table 4: Analysis of variance (ANOVA) test for MRR2

Source	Sum of squares	DF	Mean Square	F Value	Prob>F
A-Current	0.072	1	0.072	78.17	0.0003
B-Voltage	3.279E-	1	3.279E-	3.58	0.1171
C-Pulse on	0.014	1	0.014	14.74	0.0121
AB	8.590E-	1	8.590E-	9.37	0.028
Residual	4.582E-	5	9.163E-		
Lack of fit	2.258E-	3	7.528E-	0.65	0.6539
Core total	0.11	10			
R^2-	0.8563	Adj-R^2	0.7604	Pred R^2	0.5968

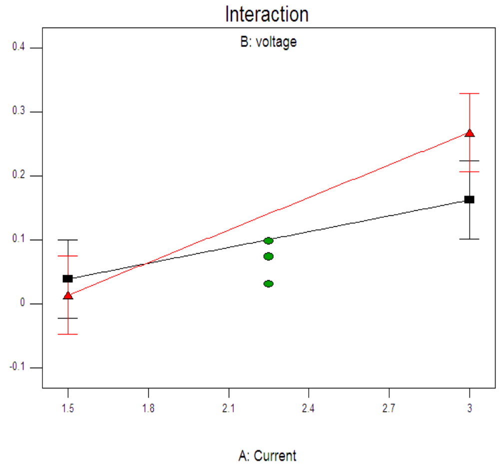

Fig 4. Effect plot showing variation of MRR2 with process parameters

4. CONCLUSION

The current study was aimed to examine the possibility of the improvement of material removal rate of AL6061 in Micro-EDM using Fe_2O_3 nano-powder-mixed dielectric. The conclusions of this experimental study are as follow:

- The ANOVA analysis for MRR1 and MRR2 responses summarized that current, voltage, and two-level interaction between voltage and current were significant factors. Findings showed that with the increase of current, MRR increased, too. This was due to the rising amount of heat and energy transmitted to the workpiece for melting and vaporization.
- During the fine-finish powder-mixed Micro-EDM of AL6061, if 4g/l Fe_2O_3 nano-powder is added to dielectric liquid, MRR can be improved.

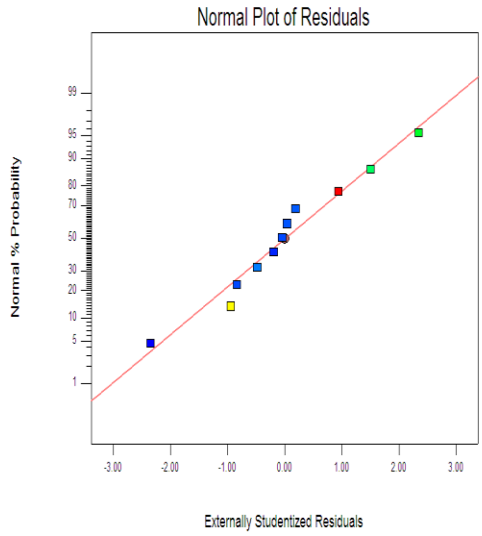

Fig 5. Show normal plot of residuals for MRR1

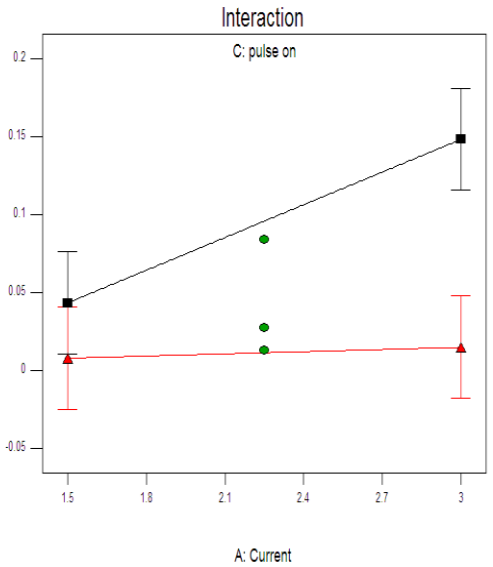

Fig 3. Effect plot showing variation of MRR1 with process parameters

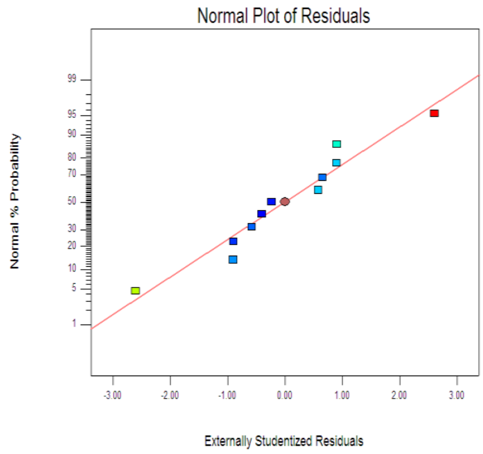

Fig 6. Show normal plot of residuals for MRR2

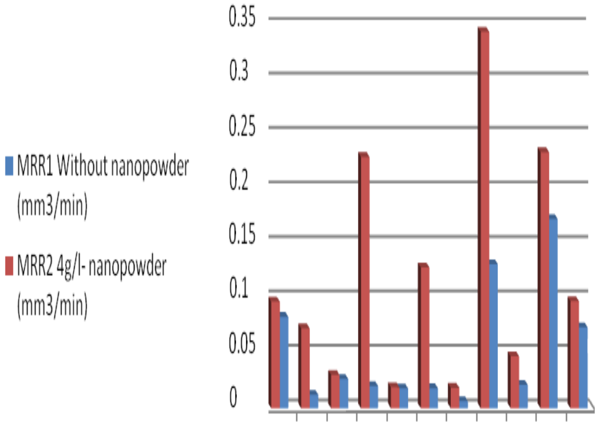

Fig 7. Material removal values

5. REFERENCES

1. Singh, S., S. Maheshwari, and P.C. Pandey, *Some investigations into the electric discharge machining of hardened tool steel using different electrode materials.* Journal of Materials Processing Technology, 2004. **149**: p. 272-277.
2. Bilal, A., et al., *Electro-Discharge Machining of Ceramics: A Review.* Micromachines, 2019. **10**(1): p. 10.
3. Maity, K.P. and M. Choubey, *A review on vibration-assisted EDM, micro-EDM and WEDM.* Surface Review and Letters, 2018. **26**.
4. Joshi, A.Y. and A.Y. Joshi, *A systematic review on powder mixed electrical discharge machining.* Heliyon, 2019. **5**(12): p. e02963-e02963.
5. Sankaran, K.K. and R.S. Mishra, *Chapter 4 - Aluminum Alloys*, in *Metallurgy and Design of Alloys with Hierarchical Microstructures*, K.K. Sankaran and R.S. Mishra, Editors. 2017, Elsevier. p. 57-176.
6. Jahan, M.P., M. Rahman, and Y.S. Wong, *Modelling and experimental investigation on the effect of nanopowder-mixed dielectric in micro-electrodischarge machining of tungsten carbide.* Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 2010. **224**(11): p. 1725-1739.
7. Assarzadeh, S. and M. Ghoreishi, *A dual response surface-desirability approach to process modeling and optimization of Al2O3 powder-mixed electrical discharge machining (PMEDM) parameters.* The International Journal of Advanced Manufacturing Technology, 2012. **64**.
8. Kansal, H.K., S. Sehijpal, and P. Kumar, *Effect of silicon powder mixed EDM on machining rate of AISI D2 die steel.* Journal of Manufacturing Processes, 2007. **9**: p. 13-22.
9. Jahan, M.P., M. Rahman, and Y.S. Wong, *Study on the nano-powder-mixed sinking and milling micro-EDM of WC-Co.* The International Journal of Advanced Manufacturing Technology, 2011. **53**(1): p. 167-180.
10. Elsiti, N.M. and M.Y. Noordin, *Experimental Investigations into the Effect of Process Parameters and Nano-Powder (Fe2O3) on Material Removal Rate during Micro-EDM of Co-Cr-Mo.* Key Engineering Materials, 2017. **740**: p. 125-132.