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EXPERIMENTAL INVESTIGATIONS ON MACHINING CHARACTERISTICS OF Al 6061-%0.5Ce METAL MATRIX COMPOSITES PROCESSED BY ELECTRICAL DISCHARGE MACHINING

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Abstract: Aluminum and its alloys such as Al6061 have many characteristics like low density, high electrical and thermal conductivity, and resistance to corrosion. The addition of cerium to some alloys led to improve the structure and mechanical properties of alloys. Through the thermal erosion process of Electrical Discharge Machining (EDM), an electrically-produced spark vaporizes materials that are electrically conductive. This paper examines the viability of improvement of material removal rate in electric discharge machining of AL6061-%0.5Ce. For the purpose of this research, a copper electrode with a 500µm diameter was utilized. The performance measures of the machining process were investigated regarding the material removal rate (MRR). Current, pulse on time, and polarity were the process parameters. Findings showed that current and pulse on time are significant parameters.

Keywords: MRR, Al6061, EDM, Copper .

I. INTRODUCTION

EDM is non-traditional machining process depends on thermoelectric energy between two electrodes. During this process, a series of discrete discharges are used to remove the material electro thermally between two electrically conductive parts that are electrode and work piece. Performance of this process depends on the design of material, and manufacturing method of the electrodes [1]. Modern industry promotes the use of alternative advanced materials (composites, super alloys and ceramics) for establishing design and manufacturing. These industrial applications demand materials with a specific set of properties, which has led to the development of composite materials consisting of two or more physically and/or chemically distinct phases [2]. Aluminum matrix composites (AMCs) are high-potential materials for many manufacturing sectors including automobiles, aerospace, electrical, military, sports and engineering components, owing to their better technological properties [3]. AMMCs have been the most exploited material for its low density and the ease of fabrication [4]. They offer a range of property enhancements over conventional engineering materials (monolithic) due to their higher strength-to-weight ratio, high bending stiffness, improved high-temperature properties, better wear resistance, corrosion resistance, good damping characteristics and lower thermal expansion [5]. Aluminum and its alloys such as (Al6061, Al5083) have many characteristics like low density, high electrical and thermal conductive, resistance to corrosion. A lot of these alloys are fabricated by virtue of high ductility, and they can maintain their ductility at very low temperatures [6]. The main elements of aluminum alloys are (copper, silicon, magnesium, zinc, manganese). Aluminum is used as conductor material [7]. In the present years, addition the rare earth elements to aluminum alloys has been studied by many researchers. There is a claim which is addition of cerium to some alloys led to improve the structure and mechanical properties of alloy [8]. The addition of cerium increases the tensile strength and hardness, but reduces the elongation [9]. The addition of cerium improves the mechanical properties. The structure refinement is one of the most important methods for improving the strength of alloys; besides the presence of spheroidal silicon particles and inter metallic compounds of cerium (Al2Ce, Al4Ce,SiCe and SiCe4) [10]. Cerium has low resistivity coefficients and atomic radii that are relatively different from that of aluminum. These characteristics cause solute element to react with crystal defects such as dislocations and grain boundaries and enhance the mechanical properties of the base metal favorably [11]. All the alloys investigated which contain Ce having the highest strength companied by low ductility compared to alloy free Ce. The improvement of mechanical properties is ascribed to the grain refining. On the other hand, the tensile strength and hardness show a more increase with a suitable Ce addition in the range (0.43 to 0.54 wt%) which have major grain boundaries and the best

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grain refining, excess of Ce > 0.54 wt% reduce its useful effect [12]. In this research cerium was added to AL6061 alloy with percentage of 0.5%.

II. EXPERIMENTAL CONDITIONS AND PROCEDURES

The experiments in the present research were conducted on an AG40L Sodick electrical discharge machine (see Fig.1). A500μm-diameter copper electrode was chosen. Depth of the holes on AL6061-%0.5Ce was2mm and the electrode. The peak current, pulse on time, and polarity were chosen as input variables for the analysis of MRR. Designing of the experiments was done using 2-level full factorial design that was consisted of 14 runs including (2^3) two-level factorial design points and 3 center points. The computation of MRR was done on the basis of the volume of material removed from the workpiece divided by machining time. A precision electronic balance was used to weigh the electrode and workpiece. Its digital weighing scale had0.0001-g precision.

Table 1: Machining parameters and their levels

Symbol	Independent Parameters	Levels	
		Low	High
A	Peak current (A)	2	3
B	Pulse on time (μs)	10	200
C	polarity	+	-

Table 2: Experimental plan and results

No	Current	Pulse on time	Polarity	MRR
1	2	10	-	0.049334
2	3	10	-	0.221791
3	2	200	-	0.0312275
4	3	200	-	0.41389
5	2	10	+	0.022147
6	3	10	+	0.12643
7	2	200	+	0.21246
8	3	200	+	0.433737
9	2.5	105	-	0.211036
10	2.5	105	+	0.1322
11	2.5	105	-	0.21829
12	2.5	105	+	0.2274
13	2.5	105	-	0.131182
14	2.5	105	+	0.21269

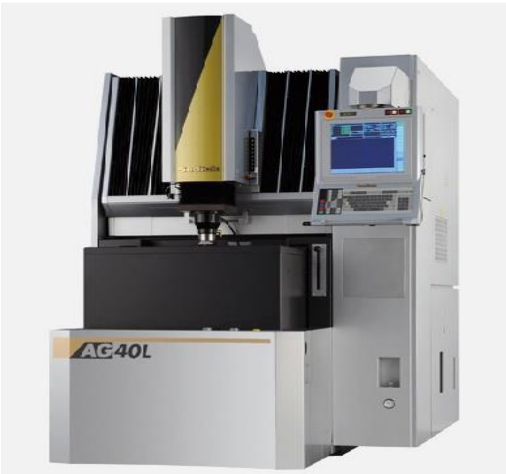

Fig. 1 AG40L Sodick electrical discharge machine

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III. RESULTS AND DISCUSSIONS

Table 2 displays the experimental plan and results for MRR. The dependent variables of the experiment were analyzed using the software Design-Expert Ver. 7. ANOVA (Analysis of variance) was conducted for testing the significance of the EDM and of AL6061-% 0.5Ce model, individual model terms, and the lack of fit. The ANOVA result of MRR is presented in Table 3 . As shown by the MRR response, A and AB factors had significant effect on the material removal rate. Furthermore, B (current) was shown as the factor of the highest significance. The lack of fit was shown insignificant, which was desired for the MRR response. By means of a backward elimination regression, all of the insignificant factors can be removed from the model; thus, a better model can be generated .Results obtained for MRR demonstrated that R-squared value (0.7737) which approach 1 is desirable. Additionally, little difference exists between Adj R-squared and Pred R-squared less than 0.2, which means that the model have a satisfactory transaction between input and output parameters. Adeq precision greater than 4 is desirable since it computes the signal-to-noise ratio. Accordingly, the final regression model in terms of actual factors for the prediction of MRR is presented as follow:

$$MRR = +0.19 +0.11 * A + 0.084 * B$$

Table 3: ANOVA table for MRR after the backward elimination regression

Sourec	Sum of Square	df	Mean Square	F value	P value	
Model	0.15	2	0.077	15.39	0.0012	signifcant
A-A	0.097	1	0.097	19.46	0.0017	
B-B	0.056	1	0.056	11.32	0.0083	
Lack of fit	0.035	5	0.00698	2.81	0.1689	not signifcant
Cor total	0.2	13				
R^2	0.7737	**Adj R^2**	0.7234			

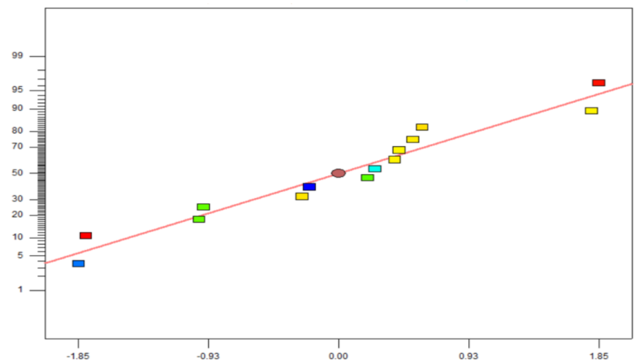

Fig. 2 Normal plot of residuals for MRR

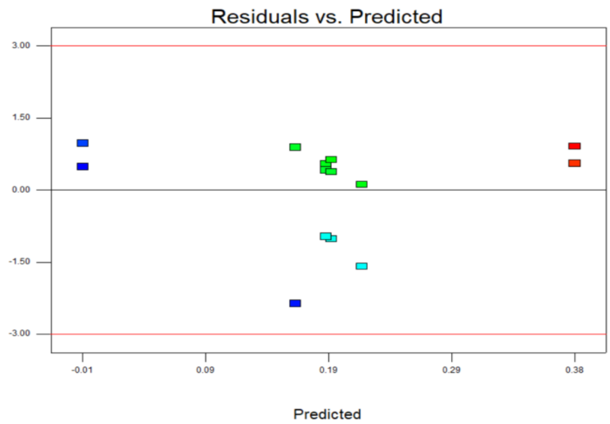

Fig. 3 Residuals versus predicted for MRR

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IV. CONCLUSION

The ANOVA analysis for MRR responses summarized that current, pulse on time were significant factors. Once the current was 3A and pulse on time was 200v, the highest value of MRR was obtained. Findings showed that with the increase of current and pulse on time MRR increased, too. This was due to the rising amount of heat and energy transmitted to the workpiece for melting and vaporization.

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