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Surface Quality Analysis of Titanium Alloy in Electrical Discharge Machining Using Aluminum Electrode in Fine Machining

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ABSTRACT

Surface roughness is an indicator commonly surveyed in other previous studies and the quality of the surface due to surface roughness (SR) reduction reduces machining time of the machining operations. This paper report on the results of SR in electrical discharge machining (EDM) using aluminum electrode for titanium alloy. The process parameters: pulse on-time, electrical current and voltage were used, and researh method was the Taguchi. The influence of the parameters to SR was evaluated through the average value. Results showed that, the parameters pulse on-time and voltage is the most influence to surface roughness (SR). Analysis of the surface layer after EDM using aluminum electrode has shown that the quality of the surface layer has been increased significantly.

Keywords: electrical discharge machining; Titanium; Surface roughness; Taguchi method..

1. INTRODUCTION

Electrical discharge machining (EDM) is a method most commonly used for the fabrication of surface molds. Its use is particularly intense when very complex shapes on hard materials with a high geometrical and dimensional accuracy are required [1]. Moreover, there is no direct contact between the electrode and the work piece; this eliminates the mechanical stresses, chatter, and vibration problems associated with traditional machining [2]. However, Machining by EDM with low machining productivity and machining surface quality is not high and this leads to increased manufacturing costs of its [2]. The surface layer after using electrical discharge machining with the topography, metallurgical and physicochemical properties is changed considerably [3, 4]. Especially, EDMed surface has a white layer having microscopic cracks with very low toughness [5] which reduce the ability of the working dies. These variations of surface layer have reduced the working ability of mould, so that we need some methods to increase the surface quantity of it. Prior research has shown that, during machining of the workpiece, material is transferred from the electrode material through the plasma onto the surface of workpiece is also appreciable [6]. Other studies of compacted Ti powder electrodes have reported improvement in the working lifespan of the die by a factor of three to seven times [7-9]. The large number of parameters of technology, machining mechanism is unclear and process optimization always require exact values of the process parameters. And this has caused many difficulties in research on EDM.

This study will investigate the influence of parameters: current, pulse on-time, voltage to SR of titanium alloy in fine machining by EDM method, and Taguchi method were used in this study. And surface quality after EDM has been clarifyl.

2. EXPERIMENTAL PROCEDURE

Experiments were conducted using a die-sinking EDM platform, a model AG40L CNC from Sodick, Inc. USA. The material used for workpiece was Ti-6Al-4V. The workpiece dimension was 100 × 80 × 25 mm3. The tool materias selected for this investigation was Al has excellent electrical and thermal conductivity and is a major commercial material. The following material parameters were studied during the course of this experiment: surface roughness, and surface appearance. Three readings were taken for each work specimen to compute the final, average measurement. Surface roughness was measured using a SJ-301 from Mitutoyo, Japan. After EDM, the samples were cleaned and the cross-section of die-sink surface machined. An optical microscope was used to study the change in the microstructure of the EDMed surface

The overall objective was to create a product with the highest quality and lowest price. These methods were based on traditional experimental design, following the Taguchi method, which can examine the influence of process parameters, specific to the quality of the production process and cost. There are many orthogonal array's available in the Taguchi's method, therefore selection depended upon the number of factors and degrees of freedom of each factor. In this study, three main factors were considered. Three of the main factors had 4 levels, with each having 3 degrees of freedom. Thus, the total sum of degrees of freedom was 3. Therefore, based on the 9 degrees of freedom, the L16 orthogonal array suited. The analysis of variance (ANOVA) was based on data obtained from Taguchi's experimental design and was used to select new parameter values to optimize the quality characteristics..

3. RESULTS AND DISCUSSION

Result of machining surface roughness is evaluated by value of SR. Each experiment was repeated 3 times. Minitab software is currently being used very common to analyze experimental results. The results are processed using Minitab 17 to determine the average value of SR. The results are shown in Table 1. From SR ANOVA Table 1, the results found are, current and pulse-on time with 100% and 97.1% confidence levels respectively they are the most notable parameters affecting SR followed by gap voltage. ANOVA average value of surface roughness ( ) is shown in Table 1 with 90% confidence intervals. From the results of ANOVA showed that: I (F = 161.13) and Ton (F = 6.19) are the single most influential factor to reach SR. The process parameter V negligible influence on SR, Table 1. I have the greatest degree of influence, the next turn is the pulse on-time,... and lowest V.

. Increase in current and pulse on time shows the increase in the surface roughness (SR) which can be determined from main effects graph, thereby increasing temperature leading to premature melting of the tool electrode. Therefore, as the current level is increased the surface roughness is increased due to increment in the spark energy. Main effects plot for SR is shown in Figure

Table 1. ANOVA of SR using Aluminum Electrode

Source	DF	SS	MS	F-Value	P-Value	Contribution %
I	3	24.3974	8.13246	161.13	0	95
Ton	3	0.9366	0.31219	6.19	0.029	3.64
V	3	0.0426	0.0142	0.28	0.837	0.16
Error	6	0.3028	0.05047			0.01
Total	15	25.6794				
S = 0.224656 ; R-Sq = 98.82%; R-Sq(adj) = 97.05%						

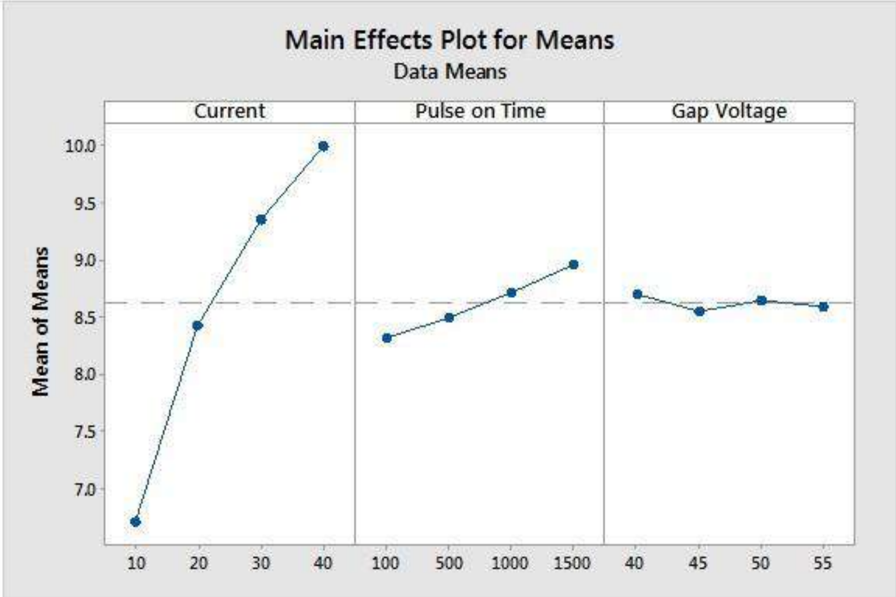

Figure 1. Main Effect Plot for SR using Aluminum Electrode

The images presented in Figures 2 and 3 demonstrate that both the topography and white layer of the machined surface were poor within the optimal parameters. The results showed that the EDM surface have number of larger craters. Debris particles also appeared to be less prevalent on the EDM surface. The machined surface is composed of many craters and micro-voids, and they are arbitrarily distributed Figure 2. This is because the energies of the sparks are randomly generated and arbitrarily distributed in the machining area. Consequently, many of the globules and debris are adhered to the machining surface, Fig. 3. The external surface tension of the dielectric solution causes the geometry of craters and particles to adhere to the radius of curvature or spherical. Therefore, he adhesion strength of the particles to the machining surface can be in the form as shown in Fig. 4. And this is directly related to the method used and the finishing cost. A lot of microscopic cracks appeared on the workpiece surface after EDM, figure 5. This is because the electrode and workpiece material on the workpiece surface at very high temperatures cools very quickly, and residual thermal stress occurs at the surface layer appears. This makes it more difficult to choose the correct removal thickness for the next finishing..

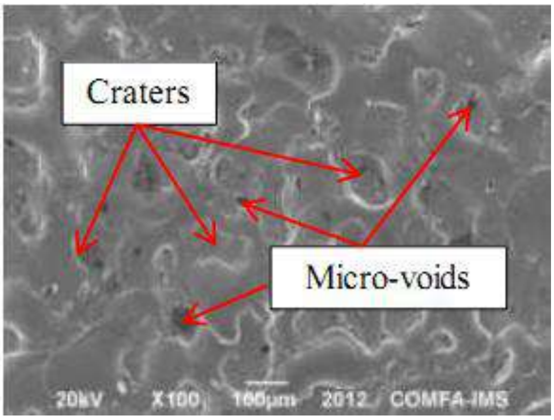

Fig. 2. EDM surface morphology

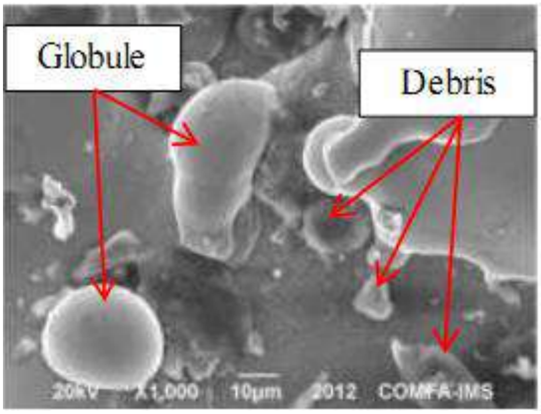

Fig. 3. Surface texture after EDM

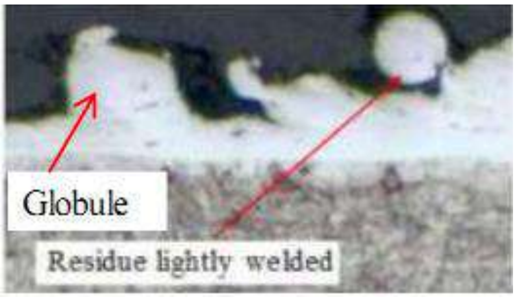

Fig. 4. Globule formation and residue of melted material in recast layer

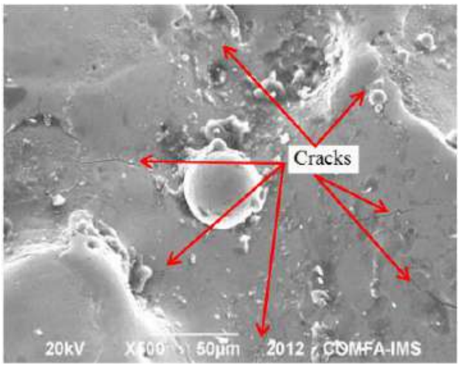

Fig. 5. Cracks distribution

4. CONLUSION

In the present study, the surface layer of the Ti-6Al-4V in EDM using Al electrode was analyzed and evaluated.From the experimental investigation, the following conclusions were made. Peak Current (Ie) is the most significant influence and V is the insignificant influence on surface morphology. The main research directions include integrating vibration into the EDM process can lead to the smallest S and the size of the SR to be more uniform. The utilization of suitable powder mixed in the dielectric fluid in EDM can reduce the size of the RLT considerably. The microscopic structure and mechanical properties of the surface machined layer have negative impact on the ability of the mold. In contrast, the heat affected zone has a higher hardness than the base metal so that it will improve the ability of the mold. There must have research studied on the effect of various parameters to reduce or completely remove a layer white at the surface of a workpiece.

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