

Analysis of Optimization of Machining Parameter to Titanium Alloy Using Micro EDM

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Abstract— In this paper investigates the effects of the micro-EDM process parameters on response variables, to determine their optimal values in order to understand the behavior of each parameter. While, there are a substantial amount of journalism studying different aspect of micro-EDM, most of them are designed based on the one-factor-at-a-time(OFT) experiments as an alternative of studying all factors, simultaneously. This paper is conducted through a series of experiments using a full factorial design. An analysis of variance was engaged to analyze the findings and to determine effect and the significance of each process parameters on the response variables. The process parameters included such as voltage, electrode rotational speed, capacitance, and electrode coating. Voltage and capacitance are studied separately as well as in combination in terms of the discharge energy. Response variables are consisted of machining time, tool wear, crater size, micro hardness, and element categorization. The surface morphology and element characterization are studied through the application of the SEM.

Key words: Micro-EDM, Tool Wear, ANOVA

I. INTRODUCTION

In this paper, the RC-type micro-EDM machine was utilized to conduct an experimental study to find out models, equations, or techniques to describe the relationship between the micro-EDM process parameters and the response variables in micro-EDM of Ti-6Al-4V alloy based on a full factorial design. An analysis of variance (ANOVA) and a multivariate analysis of variance (MANOVA) were used to determine the significance of the effects of the micro-EDM process parameters on the response variables. The regression analyses were conducted to find out the models and equations showing the relationship between the process parameters and the response variables. The optimal process parameters for two sets of response variables were determined using Minitab 17

II. PROBLEM STATEMENT

The problem raised in this paper, based on the literature review, was defining models, equations, or techniques to describe the relationship between the micro-EDM process parameters and the response variables. The process parameters included voltage, capacitance, discharge energy (the combination of voltage and capacitance), electrode rotational speed, and titanium nitride (TN) coating. The response variables consisted of machining time, tool wear, microhardness, crater size, and element characterization. The research problem was limited to the use of the RC-type micro-EDM for generating micro- features, i.e. blind holes and slots, on Ti-6Al-4V alloy.

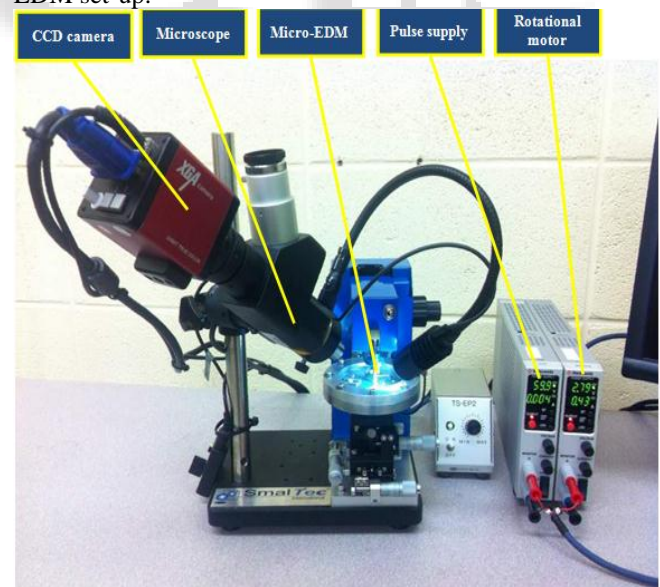
III. PURPOSE OF THIS PAPER

Three objectives are defined in this research. The first objective is to identify the level of importance and effects of the micro-EDM process parameters on the response variables, including their main effects and interaction effects. The second objective was to determine the optimal values of the micro-EDM process parameters, providing that all response variables have an identical weight and importance. The third objective was demonstrating the role and the importance of the application of a full factorial design as well as an analysis of variance (ANOVA) and a multivariate analysis of variance (MANOVA) in the micro-EDM process improvement in the context of research centers and R&D departments.

IV. METHODOLOGY

A. The micro-EDM set-up

A die-sinking micro-EDM machine using RC-type pulse supply is utilized in this study. The machine is ED009 model by Small Tech. The CCD camera and microscope are used for better monitoring of the micro- electrodischarge machining. The dielectric is the EDM oil. Figure 3 shows the micro-EDM set-up.



V. MATERIAL

All trials were conducted on Ti-6Al-4V alloy (grade 5). The characteristics of Ti- 6Al-4V alloy used in this experiment are shown in Table 2. Three plates of Ti-6Al-4V alloy were used in this study. All plates were part of a bigger plate and they were isotropic.

The chemical composition and mechanical properties of Ti-6Al-4V.

Chemical composition	
Ti	Balance
Al	5.5 – 6.67%
V	3.5 – 4.5%
O	0.2%
C	0.08%
N	0.05%
Mechanical properties	
Density (Kg/m ³)	4430
Melting point (°C)	1650
Electrical resistivity (fi-cm)	0.000178
Thermal conductivity (W/m-K)	6.7

VII. PROCEDURES

This experimental paper included three sets of trials. The first set of trials was for measuring machining time and tool wear. This set consisted of 54 trials with three replications, viz., 162 blind holes. The depth of these holes is 20µm. In preliminary experiments, it was revealed that increasing the depth of the blind holes would result in a higher number of DC arcs or abnormal discharges. Increasing the frequency of the DC arcs was done mainly because of the lack of a servo control system in the micro-EDM machine.

VII. RESPONSE VARIABLES

Response variables included machining time, tool wear (Δl), surface microhardness (VH), crater size, and element characterization.

VIII. RESULTS AND ANALYSIS

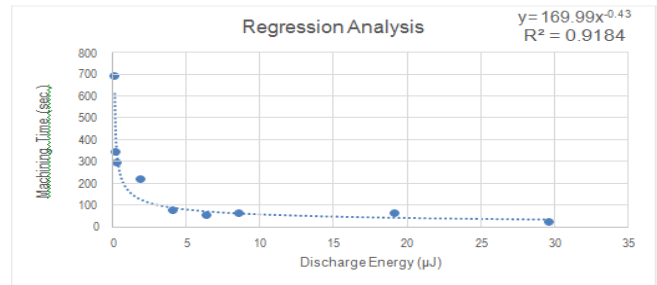
1) Machining Time

Results

Machining times for blind holes with 20-µm depth are measured for different EDM parameter settings. Increase the accuracy of the measurements, each trial is repeated three times. Tables show that the resulting data for producing the blind holes using WC tools as well as TN-WC tools, respectively.

Discharge Energy (µJ)	WC Electrode		TN-WC Electrode		Average Machining Time (sec.)
	Trial #	Machining Time (sec.)	Trial #	Machining Time (sec.)	
0.05	1, 2, 3	683	28, 29, 30	713	699
0.12	10, 11, 12	363	37, 38, 39	340	350
0.19	19, 20, 21	363	46, 47, 48	238	300
1.8	4, 5, 6	306	31, 32, 33	142	224
4.05	13, 14, 15	117	40, 41, 42	43	80
6.27	22, 23, 24	80	49, 50, 51	35	57
8.46	7, 8, 9	52	34, 35, 36	84	67
19.04	16, 17, 18	101	43, 44, 45	41	73
29.48	25, 26, 27	35	52,	22	28

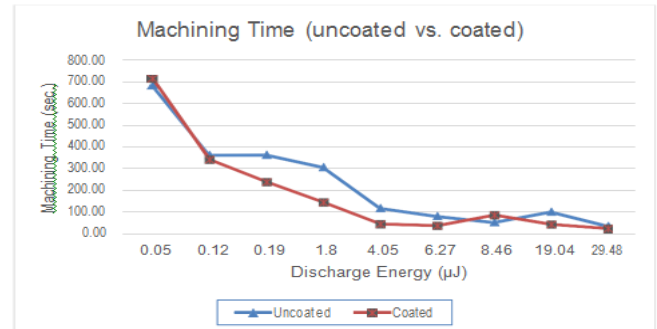
Levels of the discharge energy and machining time.



The scatter plot - the discharge energy and machining time.

2) The TN-coating and ANOVA.

The effects of TN coating on machining time for each level of discharge energy were calculated and the results are shown in Figure

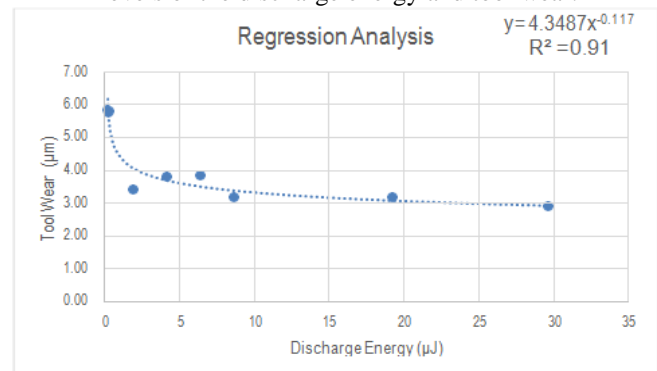


3) Tool Wear (Δl)

Results. Tool wear was calculated by measuring the difference in lengths of the electrode before and after machining (Δl)

Discharge Energy (µJ)	WC Electrode		TN-WC Electrode		Average Tool Wear (µm)
	Trial #	Tool Wear (µm)	Trial #	Tool Wear (µm)	
0.05	1, 2, 3	5.56	28, 29, 30	6.14	5.85
0.12	10, 11, 12	5.77	37, 38, 39	5.78	5.77
0.19	19, 20, 21	5.56	46, 47, 48	6.07	5.81
1.8	4, 5, 6	3.78	31, 32, 33	3.04	3.41
4.05	13, 14, 15	3.78	40, 41, 42	3.82	3.80
6.27	22, 23, 24	3.96	49, 50, 51	3.78	3.87
8.46	7, 8, 9	3.52	34, 35, 36	2.87	3.19
19.04	16, 17, 18	3.28	43, 44, 45	3.08	3.18
29.48	25, 26, 27	2.98	46,48,52,	2.88	2.93

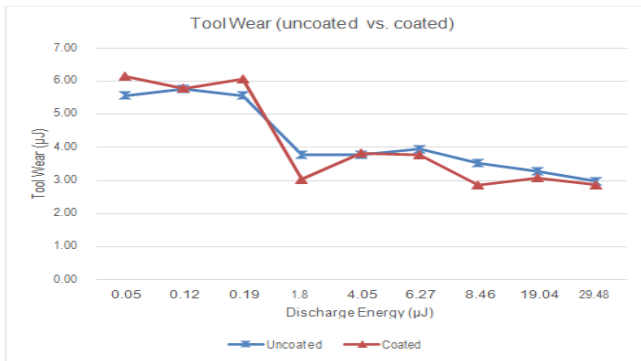
Levels of the discharge energy and tool wear.



The scatter plot - the discharge energy and tool wear

4) The TN-coating and ANOVA.

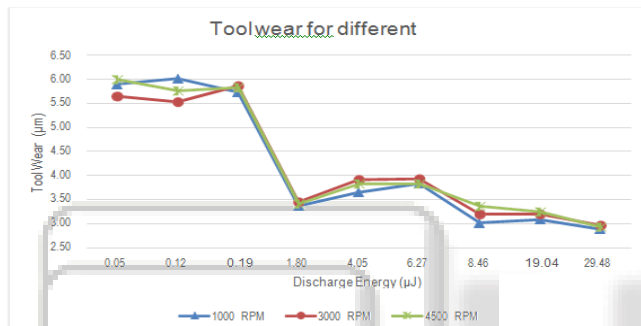
The effects of TN coating on tool wear for each level of the discharge energy are calculated and the results are shown in the Figure



The effect of TN-coating on the tool

5) *Electrode rotational speed and ANOVA.*

The effects of electrode rotational speed on tool wear for each level of the discharge energy are calculated and the results are shown in Figure 18. The values of tool wear per discharge energy for different level of electrode rotational speed are close to each other.



The effect of electrode rotational speed on the tool

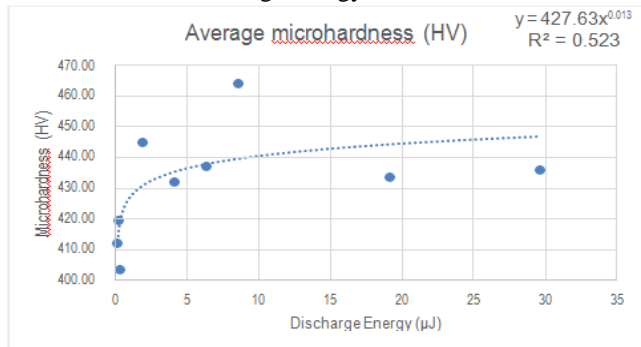
6) *Surface Microhardness*

Results

The surface microhardness of each slot is measured on two different points. since a control group, the microhardness of one point from the unmachined area besides each slot is also measured

Discharge Energy (µJ)	Point	Microhardness (HV)	Point	Microhardness (HV)	Average microhardness (HV)
0.05	1, 2, 3	414.67	28, 29, 30	409.50	412.08
0.12	10, 11, 12	428.67	37, 38, 39	410.33	419.50
0.19	19, 20, 21	403.83	46, 47, 48	403.00	403.42
1.8	4, 5, 6	437.50	31, 32, 33	452.50	445.00
4.05	13, 14, 15	420.50	40, 41, 42	443.33	431.92
6.27	22, 23, 24	443.33	49, 50, 51	430.83	437.08
8.46	7, 8, 9	467.50	34, 35, 36	460.50	464.00
19.04	16, 17, 18	430.00	43, 44, 45	437.17	433.58
29.48	25, 26, 27	438.50	46, 48, 52,	433.17	435.83

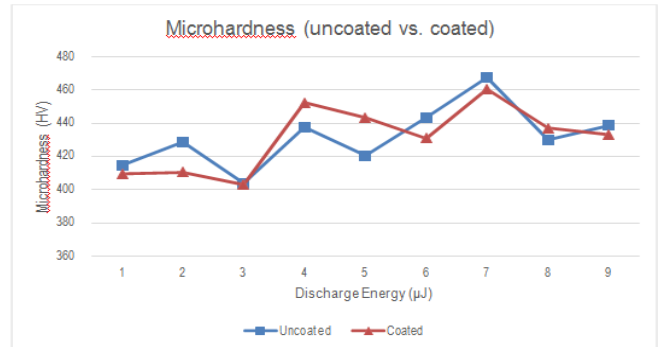
Levels of the discharge energy and the microhardness.



The scatter plot – the discharge energy and the microhardness

7) *The TN-coating and ANOVA.*

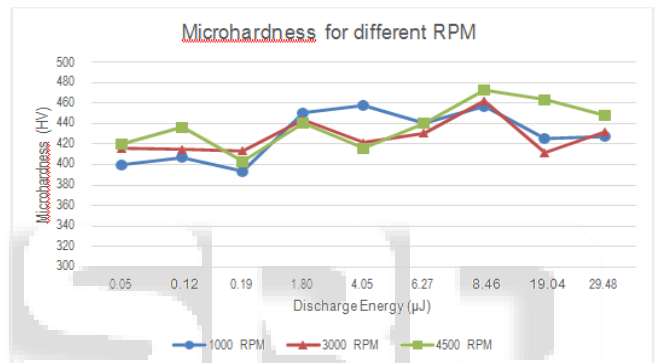
The effects of the TN coating on microhardness for each level of the discharge energy are calculated and the results are shown in Figure



The effect of TN-coating on the microhardness

8) *Electrode rotational speed and ANOVA.*

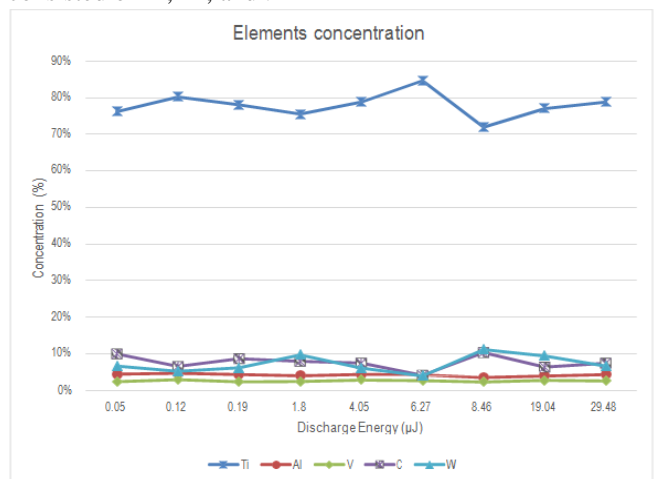
The effects of electrode rotational speed on the microhardness for all levels of the discharge energy are calculated



The effect of electrode rotational speed on the microhardness

9) *Element Characterization - EDS Analysis on the SEM Results*

The foremost chemical composition of the workpiece consisted of Ti, Al, and V



The concentration levels of the surface elements Analysis of variance (ANOVA). The results of MANOVA showed that voltage and capacitance are the significant parameters. For comprehensive study of the main effects and communication effect of these parameters on each element concentration, general factorial regression is conducted using Minitab 17.

Element characterization the main effects and the interaction effects.

Process parameters	Ti	Al	V	C	W
Voltage	Yes (varied)	Yes (increasing)	No	Yes (varied)	Yes (increasing)
Capacitance	Yes (increasing)	No	No	Yes (decreasing)	Yes (decreasing)
Voltage*capacitance	Yes	No	No	No	No
TN-coating	No	No	No	No	No
RPM	No	No	No	No	No
Other interacts. effects	No	No	No	No	No

IX. THE OPTIMAL PROCESS PARAMETERS

The combination of the optimal process parameter settings is able to identify to achieve the desired set of responses. Before finding optimal values, it is important to define the responses is included in the analysis as well as their desired values. In this revise, the important response variables are machining time, tool wear, crater size, and microhardness. Moreover, it is assumed that their weights and importance are equal. The response optimizer of Minitab 17 is used to find the optimal parameters. The confidence level of 95% is defined for all intervals.

Response	Goal	Lower value	Upper value	Weight	Importance
Machining time (sec.)	Minimum	16	897	1	1
Tool wear (µm)	Minimum	2.4	7	1	1
Crater size (µm)	Minimum	0.95	13.47	1	1

Optimal parameters				Machining time	Tool wear (Δl)	Crater size fit
Electrode	Voltage	Capacitance	RPM	fit	fit	
TN-WC	60	4700	1000	262.7 sec.	2.5µm	1.56 µm

The assumptions and the optimal values for the first set of response variables.

Response	Goal	Lower value	Upper value	Weight	Importance
Machining time (sec.)	Minimum	16	896	1	1
Tool wear (µm)	Minimum	2.4	7	1	1
Crater size (µm)	Minimum	0.95	13.46	1	1
Microhardness (HV)	Maximum	373	505	1	1

Optimal parameters				Machining time	Tool wear	Crater size	Hardness
Electrode	Voltage	Capacitance	RPM	time fit (Δl)	fit	fit	fit
TN-WC	60	4700	3000	236 sec.	3µm	1.26 µm	475.5 HV

The assumptions and the optimal values for the second set of response variables

X. CONCLUSION

In this thesis, the RC-type micro-EDM machine is utilized to conduct an experimental study in the micro-EDM of Ti-6Al-4V alloy. The purpose of this study is to determine the relationship between micro-EDM process parameters and the response variables as well as to find the optimal process parameters. After analyzing the resulting data and evaluating the results, the researcher is able to conclude about the previously stated paper questions.

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