THE INFLUENCE OF PROCESS PARAMETERS ON TWR AND OCIN MICRO EDM WITH TiN COATED WC ELECTRODE

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Abstract: The application of Mico-EDM is very popular for shaping products in the fields of molds, electronics and biomedical, etc. Therefore, improving the machining efficiency of this technology is essential, and the use of coated electrodes in micro-EDM holds great promise for quality improvement in this area. In this study, the influence of technological parameters on the quality parameters in micro-EDM with TiNcoated electrode was investigated. The Taguchi method was used to design the experiment and analyze the results. Process parameters (Voltage (U), Capacitance (C) and Spindle Rotations (SPR)) and quality indicators (tool wear rate (TWR) and overcut (OC)) were selected for evaluation in the study. Titanium alloy billet (Ti-6Al-4V) and Tungsten Carbide electrode (WC) were used for the study. The results show that, U, C and SPR all have a significant effect on TWR and C, and C is the strongest influence on TWR and U is the strongest influence on OC.

1. INTRODUCTION:

Titanium alloys are metals that contain a mixture of titanium and other chemical elements. These alloys have very high tensile strength and toughness (even at extreme temperatures). They are lightweight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. However, the high cost of raw materials and processing limits their use to military applications, aircraft, spacecraft, bicycles, medical devices, jewelry, highly stressed components and electronics.The EDM method is commonly used to process titanium alloy products. And many research directions have been proposed to improve productivity and quality in EDM for tiatan alloys including optimization of technological parameters, use of powder mixed in dielectric solution and use of coated electrodes, etc. And EDM with coated electrode is a very promising research direction in the field of processing microphone products. Therefore, research to clarify this field is very necessary.

Research results on micro-EDM have shown that: the effect of vibrations on the electrical discharges in the micro-EDM (electrical discharge machining) process was investigated [1]. The effect of SPR, Ton and workpiece vibration has been investigated on material removal rate (MRR) and surface roughness (SR). It was evident that by application of vibration onto the micro-EDM process, the machining time can be reduced significantly. The reduction or elimination of the start-up process delivers a significant part of the machining time savings. Process time decreases with increased vibration frequency and constant amplitude. The total duration of the arcing events is reduced by the application of vibration and decreases with increasing frequency. Surface defects in micro-EDM such as inhomogeneity, cracks, arc spots and black spots have been analyzed and reduced, while improving material removal rate with lower tool wear [2]. Super-finished surfaces thus generated have uniform white layer (re-solidified layer) with an average thickness below 1μm. The I has greater effect on multi-performance characteristics than Ton [3]. Electrode wear were increased with the increase in both discharge current and pulse duration almost linearly due to the higher energy density. The crack and damage characteristics of machined surfaces were reduced by decreasing the discharge current and shortening the pulse duration. Investigated the influence of high spindle speeds on machining performance [4]. The experiments were performed to investigate electrode wear by varying SPR and Ton.Influence of the Process Parameters to

Manufacture Micro cavities by Electro Discharge Machining (EDM) has [5]. Increasing demand on micro-product has driven the development of innovative manufacturing process to this new requirements as well as the adaptation of conventional metal cutting process to these micro-scale applications [6]. Two process parameters were used such that voltage and pulse on time to investigate surface topography of cavities.

Studies on EDM and Micro-EDM with coated electrodes have shown that the cost of using electrodes in micro-EDM using coated electrodes is greatly improved [7]. The cost of Cu coated Al electrode is 3 times less than that of Cu electrode. The quality parameters in EDM with MWCNT Cu-base coated electrode are significantly improved [8]. Ag coating with Cu electrode resulted in significantly improved MRR, TWR and SR [9]. Compared with the uncoated electrode, the TWR and OVC of the coated electrode are reduced, and the MRR in micro-EDM with the coated electrode is increased [10]. The coating materials (Cu-ZrB2 and ZniC) contributed to the significantly improved TWR [11, 12]. TiAlN coating material has lower machining efficiency in micro-EDM than TiN coating [13]. Different coating materials will have different effects on the quality parameters in Micro-EDM, and Micro-EDM using TiN, Ag and ZrN coated electrodes has shown that TiN coated electrode has the highest machining efficiency. The characteristics of electrode coating materials in Micro-EDM include melting, electrical and thermal conductivity, etc [14,15]. The above research results have shown that using coated electrodes in EDM can bring economic and technical efficiency in machining. However, the research results in this area are not many. And this will significantly affect the use of this technology in practice.

2. EXPERIMENTAL SETUP

The final experiments were performed by four different electrodes on Titanium Grade 5 plate of thickness 1.6mm. Electrodes of Tungsten Carbide are coated with TiN. Remaining one electrode was non-coated of 490 microns of Tungsten Carbide. The experiments had performed on a MEDM (Make: Synergy Nano Systems Model: Hyper 10). Titanium Grade 5 alloy used as workpiece material and tungsten carbide used as tool material. The dimension of the workpiece is 10×50mm. The mean diameter of the tool is 490 micron. The weight of all the tools had measured before and after each experiment on a precision analytical balance (Make: Ishida Co. Ltd., Model-DXR220) weight measuring machine. Through pilot experiments on the different process parameter values, it has been understood that negative polarity does not yield good machining. Hence all the experiments have been measured in straight polarity. Three capacitance levels are taken for study such as Level 1(100pF), Level 2 (1000pF), and Level 3 (10nF). Voltage ranges between 120-160 Volts. Initial and final weights of the tool and workpiece had measured for TWR. Experimental results for OC and TWR by varying Voltage, Capacitance and RPM as per L_9 orthogonal array are shown in Tables below.Tungsten Carbide electrode is coated with 6.663µm of TiN. The mean diameter of coated TiN electrode is 503.326 µm. TiN was coated on Tungsten Carbide Electrode with 6.663 µm of thin film to observe the impact on TWR. Same L9 orthogonal array was performed and readings of Response Variables were recorded as mentioned in Table 1. Results obtained by performance of nine experiments are mentioned in Table 1; first and Ninth experiment shows minimum and maximum values respectively for TWR and Overcut. For overcut second and ninth experiment shows maximum and minimum.

Table 1. Experimental results with TiN coated micro tool electrode

Expt. No.	Process parameters			Response variables	
	Voltage (V)	Capacitance (pF)	SPR (rpm)	TWR (mg/min)	Overcut (µm)
1	120	100	200	0.00834	60.2635
2	120	1000	400	0.045	28.6535
3	120	10000	600	0.075	54.3135
4	140	100	400	0.0234	84.0535
5	140	1000	600	0.05	33.8096
6	140	10000	200	0.0883	58.093
7	160	100	600	0.015	95.2285
8	160	1000	200	0.0416	62.2585
9	160	10000	400	0.0983	112.8685

3. RESULTS AND DISCUSSION

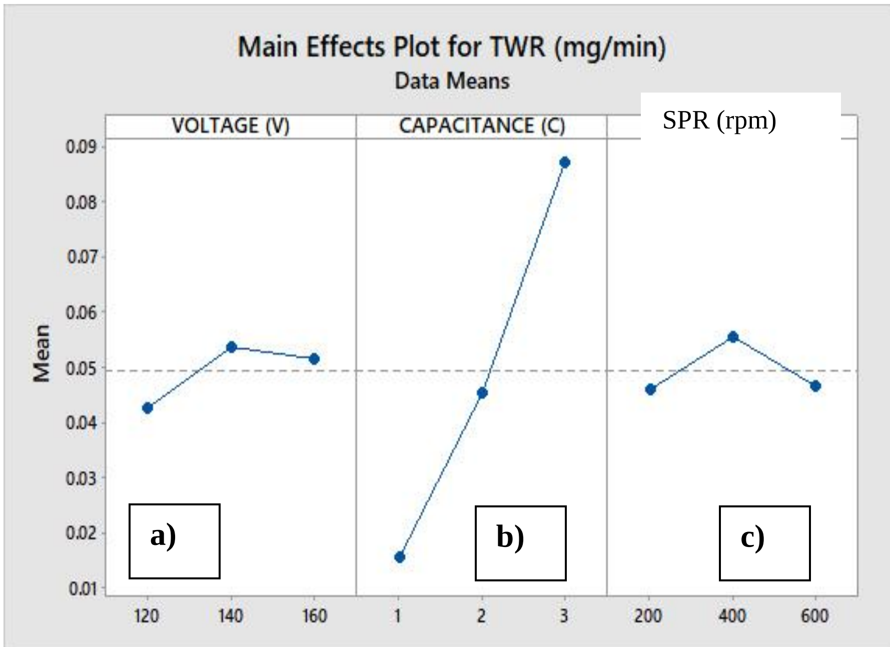
3.1. ANALYSIS OF VARIANCE FOR TWR

TWR was measured by weight reduction method. From Table 2 it was cleared that Capacitance (F = 168.21) plays dominant role in wearing of electrode but remaining parameter such as Voltage (F = 4.49) and RPS(F = 3.67)were non-significant for TWR of TiN coated micro Electrode.The percentage distribution of influence of process parameters C, U and RPS is as follows: 94.83%, 2.52 % and 2.07 %, respectively.

Table 2. Results of ANOVAfor TWR

Source	**DF**	**SS**	**MS**	**F ratio**	**P value**	**Contribution (%)**
Voltage (V)	2	0.000207	0.000104	4.49	0.182	2.52
Capacitance (pF)	2	0.007763	0.003881	168.21	0.006	94.83
SPR (rpm)	2	0.000170	0.000085	3.67	0.214	2.07
Error	2	0.000046	0.000023	-	-	0.56
Total	8	0.008186	-			
S = 0.0048036 R-Sq = 99.44% R-Sq(adj) = 97.74%						

The main effect plot for TWR of TiN Coated tools shown in Figure 1. But slightly more TWR was observed at higher voltage levels in TiN Coated Electrodes. This is due to higher spark energy. The 490 micron of Tungsten Carbide Electrode was coated with 6.663 microns of TiN by using PVD.Figure 1a showed that the increase of U led to a change in TWR, and TWR at U = 140 V is the largest and it is the smallest at U = 120 V. The increase of C led to a very significant increase in TWR, and TWR at C = 10000 pF is the largest and it is the smallest at C = 100 pF, Figure 1b. The influence of SPR on TWR is also quite similar to the influence of U, and TWR at SPR = 400 rpm is the largest and it is the smallest at SPR = 200 rpm, Figure 1c.



Figůe 1. Main Effects Plot for TWR

Optimization of TWR:

From the results of ANOVA of the mean and S/N ratio for TWR (Figure 2), the most significant main and interaction terms were obtained. These are tabulated in Table 3. TWR value is predicted at optimal conditions with the parameters that have the strongest influence.

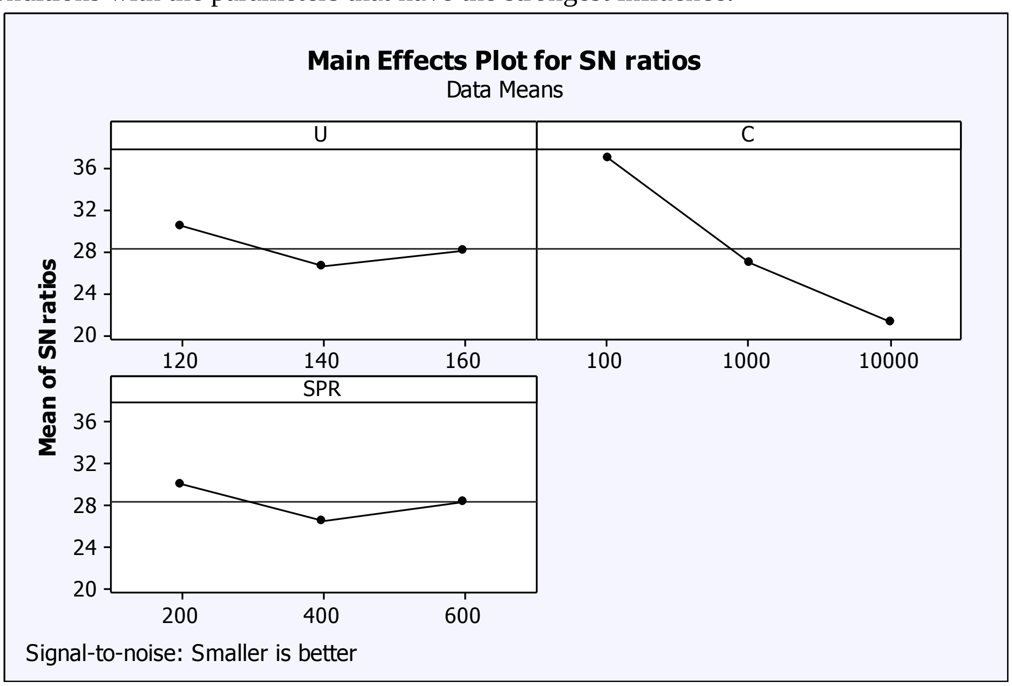


Figure 3.Main effects plot forS/N of TWR

Table 3. The levels of influence of TWR

Source	S/N of TWR
Voltage	U = 120 V
Capacitance	C =100 pF
SPR	SPR = 200 rpm

Estimated value of TWR at optimal conditions:

Estimated value of TWR at optimal conditions, U1, C1, SPR1. TWR is determined by the formula by Roy(1990) (1) [16] and TWR_{opt} = 0.0085 mg/min.

$$\overline{TWR_{opt}} = \overline{U_1} + \overline{C_1} + \overline{SPR_1} - 2.\overline{T} \quad (1)$$

3.2. ANALYSIS OF VARIANCE FOR OVERCUT

From Table 4, it it was cleared that Capacitance (F = 19.79) and Voltage (F = 22.64) play dominant role in wearing of electrode but remaining parameter RPS (F = 3.20) was non-significant for OC of TiN coated micro Electrode. The percentage distribution of influence of process parameters U, C and RPS is as follows: 48.55%, 42.44 % and 6.86 %, respectively.

Table 4. Results of ANOVA for Overcut

Source	**DF**	**SS**	**MS**	**F ratio**	**P value**	**Contribution (%)**
Voltage (V)	2	2878.3	1439.13	22.64	0.042	48.55
Capacitance (pF)	2	2516.2	1258.12	19.79	0.048	42.44
SPR (rpm)	2	406.9	203.44	3.20	0.238	6.86
Error	2	127.1	63.56	-	-	2.14
Total	8	5928.5	-			
S = 7.97423 R-Sq = 97.86% R-Sq(adj) = 91.42%						

For TiN coated Electrode, Overcut increases as voltage increase. But for Tungsten Carbide Electrodes at higher voltage level of 160V overcut decreases due to protective layer of carbon was formed at surfaces. The layer lessens the spark. Thus instead of increase in overcut, we observed reduction in non-coated electrode. From Figure 2a, it was clear that at higher voltage level (160V) overcut increases. This is due to a higher voltage as well as capacitance more heat energy generated hence coated thin film easily gets removed from substrate. This effect refuses to settle down of coated layer. Therefore, a metallic conductive particle of coatings comes in between electrode gap and them itself acts as electrode. These moving floating electrodes produce expansion of energy.When C was changed, OC was changed, and maximum of OC at C = 100 pF and it is the smallest at C = 1000 pF, Figure 2b.From Figure 2c, as whirling motion increases, overcut reduces at 200 rpm and 600 rpm. This is due to softer thin layer of coatings gets eroded at these levels because of whirling motion of tool. Also shape of the electrode becomes hemispherical at these SPR levels. Hence, at lower (200rpm) and higher (600rpm) levels Overcut was less comparatively. But at 400rpm due to proper flushing action proper plasma channel formation takes place thereby more expansion of spark occurs.

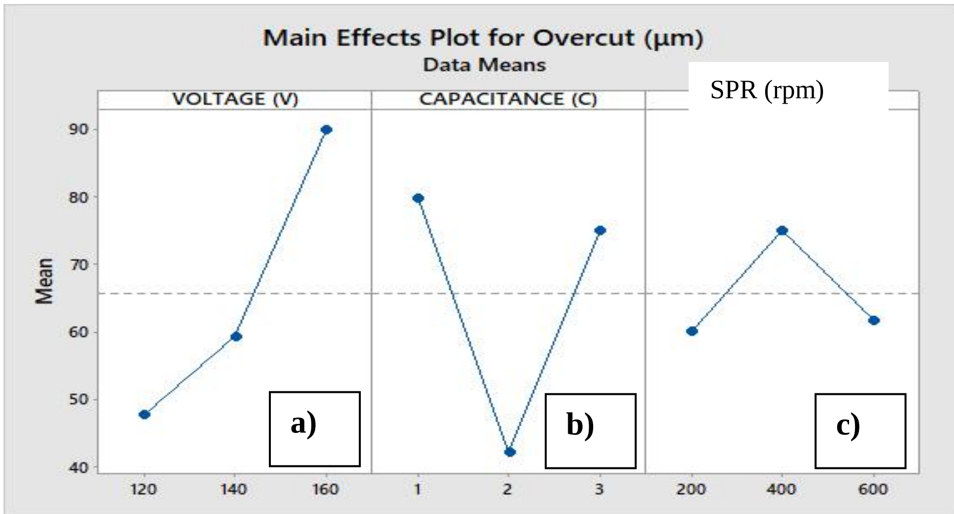
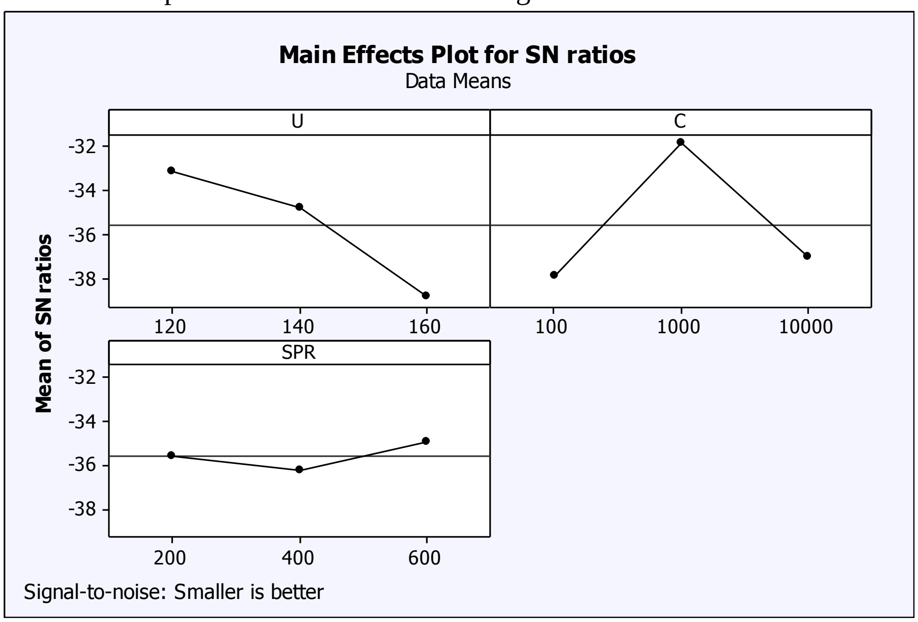


Figure 2. Main Effects Plot for Overcut

Optimization of OC:

From the results of ANOVA of the mean and S/N ratio for OC (Figure 3), the most significant main and interaction terms were obtained. These are tabulated in Table 5. OC value is predicted at optimal conditions with the parameters that have the strongest influence.



Figůe 3.Main effects plot forS/N of OC

Table 5. The levels of influence of OC

Source	S/N of OC
Voltage	U = 120 V
Capacitance	C =1000 μs
SPR	SPR = 600 rpm

Estimated value of OC at optimal conditions:

Estimated value of OC at optimal conditions, U1, C2, SPR3. OC is determined by the formula by Roy, (1990) (2) [16] OC_{opt} = 37.896 μm.

$$\overline{OC}_{opt} = \overline{U_1} + \overline{C_2} + \overline{SPR_3} - 2.\overline{T} \quad (2)$$

4. CONCLUSION

This research work was performed by Micro EDM. This study aimed at optimising TWR and OC using Taguchi methods to identify the most significant factors that influence TWR and OC. The experiments were performed using Taguchi method of design of experiments and analysis were carried out using Minitab16 software. Titanium Grade 5 (Ti-6Al-4V) used as workpiece in both cases. The L9 orthogonal array performed with varying levels of Voltage, Capacitance and RPM to obtain Response Variables such as Tool Wear Rate (TWR) and Overcut (OC) in Micro EDM process using TiN coated electrode. The ANOVA was to identify the important parameters in prediction TWR and OC. The optimal value of TWR and OC were 0.0085 mg/min and 37.896 μm.

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