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The Effect of Machining Parametersinμedm with Coated Electrode

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Abstract: *μEDM is widely used in biomedical manufacturing for machining the mciro components. In this study, quality indicators are optimally selected and the impact of process parameters on quality indicators in μEDM with coated electrodes is examined. Ti-6Al-4V workpieces were used in the experiment, and an electrode made of TiN-coated was used. The research employed certain process parameters, including Spindle Rotation (RPM), Capacitance (C), and Voltage (V). The indications in μEDM include depth (Z coordinate), overcut (OVC), and tool wear rate (TWR).*
Keywords: *μEDM, coated electrode, ANOVA.*

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I. Introduction

Numerous industries, including the automotive, biomedical, aerospace, marine, and chemical process industries, employ Ti-6Al-4V [1]. Certain materials can only be machined using traditional machining, non-conventional machining techniques including laser processing and electrochemical technologies, and this alloy through an EDM process (such as low thermo-physical phenomena and work hardening) [2]. The layer of electrode surface material created by the surface technology may range in thickness from 3 to 20 µm, which makes it suitable for the electrodes' operating needs in µEDM [3]. Studies and assessments have been conducted on the surfaces of Cu, brass, molydenum, and Cu-W electrodes in EDM coated with nickel and diamond – nickel materials [4]. When compared to uncoated Cu electrodes, TiN or TiAlN coatings enhance TWR and SR in µEDM; however, TiN coating dramatically improves quality indicators [7]. Using die sinking EDM at meso-micro scale, super-finished surfaces with Ra <0.06µm have been produced by utilizing a low stray capacitance power circuit and a unique stochastic orbiting approach. With milled, machined, or wire-eroded copper electrodes with Ra ≤0.2µm, it is possible to produce Ra values as low as 0.05µm and a uniformly dispersed white layer (re-solidified layer) with a thickness of less than 1µm [8]. Different performance parameters required the addition of fine powder to the dielectric liquid, which enhanced machining performance and guaranteed better accuracy and surface quality [9]. It was discovered from the literature that there are several EDM process parameters. The key variables that impact EDM performance are listed below [11]. Taguchi was employed in the design and analysis of the experiments.

II. Experimental Setup

The Taguchi technique was used in the experiment's design. The workpiece material utilized in this project is a titanium alloy, Ti-6Al-4V. A 6.663µm layer of titanium nitride is applied to the tungsten carbide electrode. 503.326 µm is the average diameter of the coated titanium nitride electrode. EDM oil served as the dielectric medium. It was done using Hyper 10 Micro Electric Discharge Machining. Table 1 describes the input parameters and their levels, which include voltage (U), capacitance (C), and spindle rotations (RPM). Table 1 included the L9 orthogonal array recorded readings. The three quality criteria are Tool Wear Rate (TWR), Overcut (OVC), and Z coordinate (Z), together with a 15-minute machining time. To examine the effect on TWR, 6.663 µm of thin film titanium nitride was applied to the tungsten carbide electrode. Experimental outcomes were tabulated in Table 1.

Table 1. TiN Coated Micro Electrode based experimental outcomes

Expt. No.	Input process parameters			Response variables	
	Voltage (V)	Capacitance (pF)	RPM (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

III. Results And Discussion

TWR using Titanium Nitride Coated Micro Electrode: The weight reduction method was used to calculate TWR. Table 2 demonstrated that, while the remaining parameters, such as U and RPM, were not relevant for the TWR of the titanium nitride-coated micro electrode, capacitance was clearly the most important factor in electrode wear. Which characteristics had the most impact on delivering the ideal TWR values were shown by the F values of the parameters. The S/N ratio for TWR at 90% confidence interval is displayed using an ANOVA in Table 2. C (F value 168.21) is insignificant to affect TWR, and all remaining factors are insignificant to affect TWR, table 2.

Figure 1 depicts the primary effect plot for TWR of TiN-coated instruments. However, on TiN-coated electrodes, a little bit more TWR was noted at higher voltage levels. Higher spark energy is the cause of this. PVD was used to coat 6.663 microns of titanium nitride on a 490 micron tungsten carbide electrode. Their surfaces had a thin coating placed on them. According to observations, thin film deteriorates and tool motion becomes more swirling when RPM changes to higher levels. The machine demonstrated improved tool rotation performance at 400 rpm. TWR hence happens more frequently.

Table 2. Analysis of Variance for TWR using TiN coated micro Electrode

Source	DF	SS	MS	F ratio	P value	Contribution (%)
Voltage (V(amp)	2	0.000207	0.000104	4.49	0.182	2.52
Capacitance (µs)	2	0.007763	0.003881	168.21	0.006	94.83
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%						

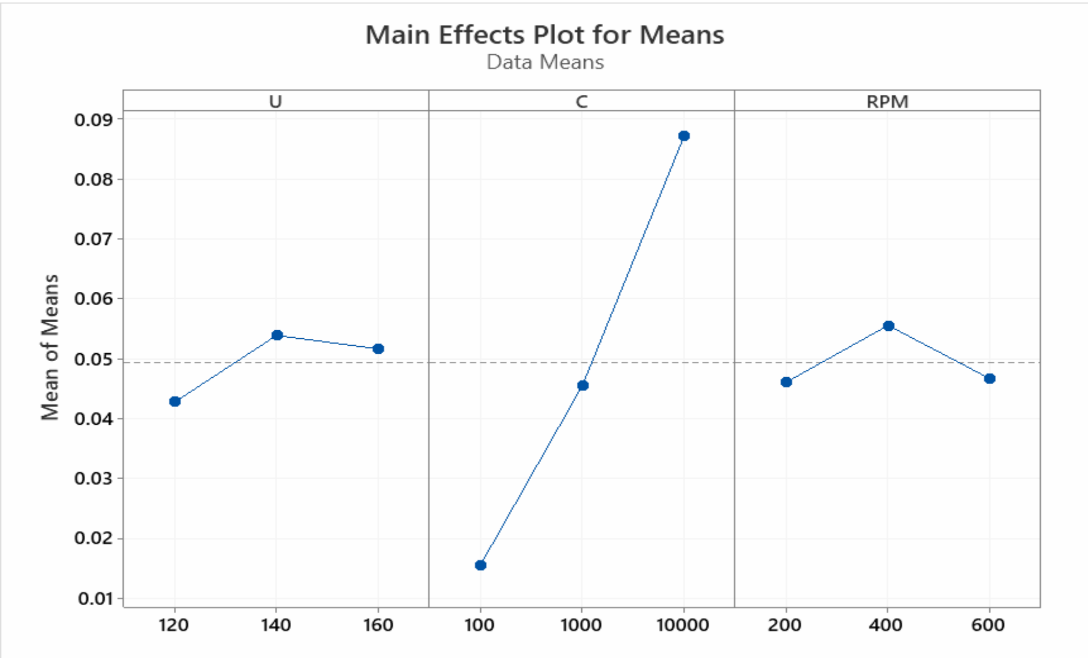

Figure 1. Main Effects Plot for TWR with TiN coated micro tool electrode

Overcut using Titanium Nitride Coated Micro Electrode: From

Table 3, it was cleared that Capacitance and Voltage plays dominant role in wearing of electrode but remaining parameter such as RPM were non-significant for Overcut of Titanium Nitride Electrode, and U (F = 22.64) and C (F = 19.79) play dominant role in Overcut.

Overcut rises with voltage for an electrode covered with titanium nitride. However, overcutting for Tungsten Carbide Electrodes drops at higher voltage levels of 160V because a protective carbon layer forms on the surfaces. Lessening the spark is the layer. Consequently, we saw a decrease in the non-coated electrode rather than an increase in overcut. Figure 2 made it evident that overcut rises at higher voltage levels (160V). This is because there is more heat energy created owing to a greater voltage and capacitance, which makes it easier for the coated thin film to separate from the substrate. This influence of the carbon layer is not going away. As a result, a coating's metallic conductive particle enters the electrode gap and functions as the electrode. Energy is expanded by these floating, moving electrodes. From Figure 2, hard tungsten carbide erodes the cavity's walls as the whirling velocity rises. However, overcut in this instance decreases between 200 and 600 rpm. This is because the tool's spinning action erodes the softer thin coating layer at these levels. At these RPM values, the electrode's form also becomes hemispherical. Therefore, overcut was decreased in comparison at lower (200 rpm) and higher (600 rpm) values. However, adequate flushing action causes proper plasma channel creation at 400 rpm, which leads to higher spark expansion.

Table 3. Analysis of Variance for Overcut using TiN coated micro Electrode

Source	DF	SS	MS	F ratio	P value	Contribution (%)
Voltage (V(amp)	2	2878.3	1439.13	22.64	0.042	48.55
Capacitance (μs)	2	2516.2	1258.12	19.79	0.048	42.44
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%						

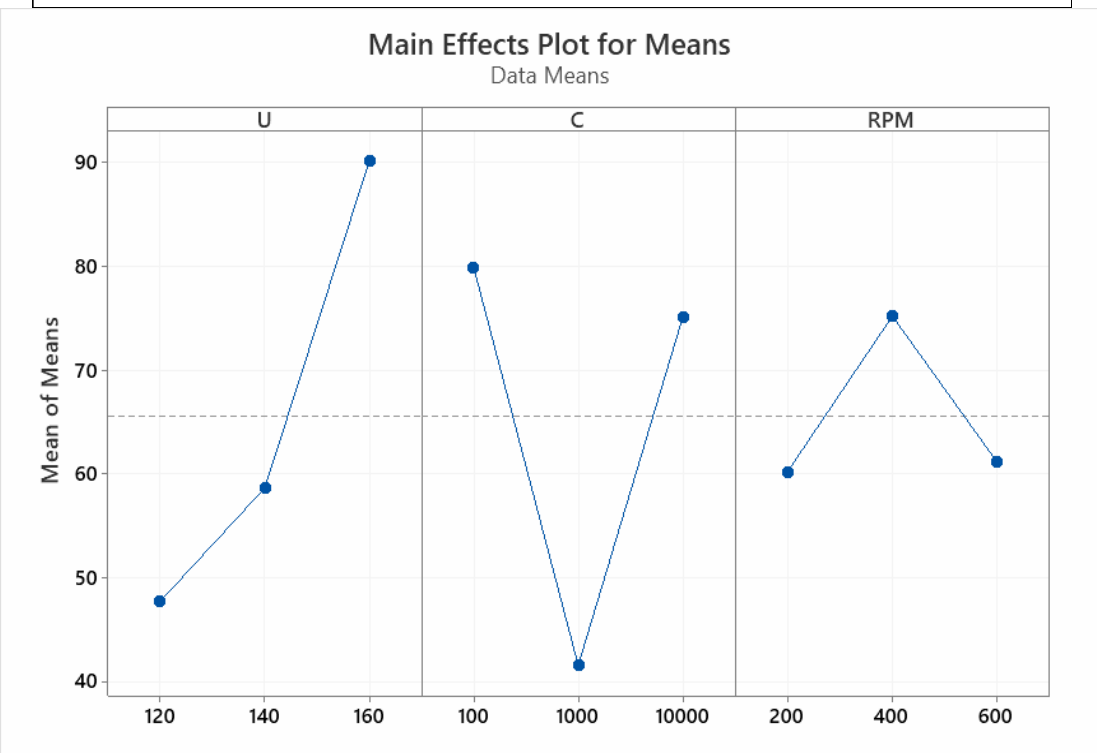

Figure 2. Main Effects Plot for Overcut with TiN coated micro tool electrode

IV. Conclusion

This work aims to target the TWR and OVC using Taguchi techniques. The influence of factors, i.e., U, C, and RPM, was examined using ANOVA. Using a TiN-coated electrode, the ANOVA was used to determine the critical TWR, OVC in the Micro EDM process. Below are some aggregated findings from ANOVA and plots:

Z and OVC are significantly increased with the increase of C, but TWR is significantly reduced. The increase in V has led to an increase in TWR and OVC, but the increase in quality indicators is not as significant as that of C.

C has a significant effect on OVC and TWR.

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