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Optimization of EDM Process Parameters on MRR & TWR of Tungsten Carbide by Taguchi Method

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Abstract: Electrical discharge machining (EDM) is a process for shaping hard metals and forming deep complex shaped holes by arc erosion in all kinds of electro-conductive materials. The objective of this research is to study the influence of operating parameters current, voltage and pulse on time on material removal rate (MRR) and tool wear rate (TWR) in EDM of Tungsten carbide. The effectiveness of EDM process with tungsten carbide is evaluated in terms of the material removal rate and tool wear rate produced. It is observed that copper is most suitable for use as the tool electrode in EDM of Tungsten carbide. In this research, trials are conducted on Tungsten carbide to observe the influence of the parameters such current, voltage and pulse on time on output characteristic MRR and TWR. The experiments are conducted by using Taguchi, DOE technique and analysis is confirmed by ANOVA and regression method. This study presented the optimal machining condition which can be used for maximize MRR and minimize TWR. The tests are confirmed by confirmation test and results are validated mathematical analysis.

Keywords: ANOVA analysis, EDM Parameters, Material Removal Rate, Tool Wear Rate, Taguchi Method

I. INTRODUCTION

Electrical Discharge Machining (EDM) is a nontraditional manufacturing process based on removing material from a part by means of a series of repeated electrical discharges (created by electric pulse generators at short intervals) between a tool, called electrode, and the part being machined in the presence of a dielectric fluid.[11,12]At present, EDM is a widespread technique used in industry for high precision machining of all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials. The adequate selection of manufacturing conditions is one of the most important aspects to take into consideration in the die-sinking electrical discharge machining (EDM) of conductive steel, as these conditions are the ones that are to determine such important characteristics: surface roughness, electrode wear (EW) and material removal rate (MRR).The material used in this study is a tungsten carbide or hard metal.

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Approximately 50% of all carbide production is used for machining applications but tungsten carbides are also being increasingly used for non-machining applications, such as mining, oil and gas drilling, metal forming and forestry tools. [11, 13]

1.1 Necessity

In EDM, the selection of parameters play a main role in producing high material removal rate and less tool wear rate. This research aim is to investigate the proper selection of parameters in EDM for machining hardened material and studies these selected different parameters which are able to deliver better results in terms of material removal rate and tool wear rate. The problem might be interfering the result in this experiment when the selection of the parameters is not suitable and improper to investigate on these machining characteristics.

1.2Objectives

The objective of this work is-

- To evaluate the performance of EDM ontungsten carbide (WC) with respect to various responses such as tool wear rate (TWR) and material removal rate (MRR).
- To establish mathematical model for all responses involved which are material removal rate (MRR) and tool wear rate (TWR).
- Taguchi method from design of experiment (DOE) used in order to analyze and determine global solutions for optimal cutting parameters of EDM operation.

II. CRITICAL LITERATURE REVIEW

Karthikeyan [01] was presented the mathematical modeling of EDM with aluminum-silicon carbide particulate composites. The effect of MRR,TWR, SR with Process parameters was taken in to consideration were the current (I), the pulse duration (T) and the percent volume fraction of SiC (25 µ size). A three level full factorial design was used. Finally the significant of the models were checked by the ANOVA. Biing Hwa [02] was investigated the feasibility and optimization of a rotary EDM with ball burnishing for inspecting the mach inability of **Al2O3/6061Alcomposite** used the Taguchi method. Three ZrO2 balls attached as additional components behind the electrode tool offer immediate burnishing followed EDM. Design of tool electrode was Copper ring shaped EDM. This EDM process approaches both a higher machining rate and a finer surface roughness.

Lee and X.P.Li [03] showed the effect of the machining parameter in EDM of tungsten carbide on the machining characteristics.

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The EDM process with tungsten carbide better machining performances was obtaining generally with the electrode as the cathode and the work piece as anode. Tool with negative polarity gave the higher material removal rate, lower tool wear and better surface finish. B. Mohan and Satyanarayana [04] evaluated the of effect of the EDM Current, electrode polarity, pulse duration and rotation of electrode on metal removal rate, TWR, and SR, and the EDM of **Al-Sic with 20-25 vol. % SiC**, Polarity of the electrode and volume present of SiC, the MRR increased with increased in discharge current and specific current it decreased with increasing in pulse duration.

Tsai et al [05] studied that the electrodes made by powder metallurgy technology from special powders was used to modify EDM surfaces in recent years, to improve wear and corrosion resistance. Electrodes was made at low pressure (20 MPa) and temperature (200 °C) in a hot mounting machine The recast layer was thinner and fewer cracks were present on the machined surface. P. Narender Singh [06] discussed the evolution of effect of the EDM current (*C*), Pulse ON-time (*P*) and flushing pressure (*F*) on MRR, TWR, taper (*T*), OC, and surface roughness (SR) on machining as-cast **Al with 10% SiCp** . ELEKTRAPULS spark erosion machine was used for the purpose and jet flushing of the dielectric fluid, kerosene, was employed. Brass tool of diameter 2.7mm was chosen to drill the specimens. ANOVA was performed and the optimal levels for maximizing the responses were established.

The effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of high-speed steel were investigated by **Yan-Cherng** et.al [07]. Experimental design was used taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by ANOVA and F -test. During the experiment MRR increases with peak current. Dhar and Purohit [08] evaluated the effect of current (c), pulse-on time (p) and air gap voltage (v) on MRR, TWR, OC of EDM with **Al–4Cu–6Si alloy–10 wt. % SiCP composites**. The significant of the models were checked using technique ANOVA and finding the MRR, TWR and OC increase significant in a non-linear fashion with increase in current. Yan-Cherng Lin [09] was reported that Electrical Discharge Energy on Machining of **Cemented Tungsten Carbide** used an electrolytic copper electrode. The machining parameters of EDM were varied to explore the effects of electrical discharge energy on the machining characteristics, such as MRR, EWR, and surface roughness. Tool electrode material such as **Al–Cu–Si–Tic composite** produced by powder metallurgy (P/M) technique and used as work piece material CK45 steel was shown by **Taweel** [10]. The central composite second-order rotatable design was utilized to plan the experiments, and RSM was employed for developing experimental models.

S. H. Tomadi, M. A. Hassan, Z. Hamedon [11] studied that the influence of the parameters such peak current, power supply voltage, pulse on time and pulse off time. Material removal rate (MRR) and electrode wear (EW) in this experiment was calculated by using mathematical method. The result of the experiment then was collected and analyzed using STATISTICA software. This was done by using the design of experiments (DOE) technique and ANOVA analysis**.**

Puerto's, I., Luis, C.J. and Alvarez, L. [13] carried out on the influence of the factors of intensity, pulse on time and duty factor over machining characteristics such as surface roughness, electrode wear and material removal rate. Mathematical model was obtained using the technique of design of experiments to select

III. EXPERIMENTAL PROCESS

It consist of following main points-

A. Work piece material and its properties-

In this experiment Tungsten Carbide is selected as the work piece material and properties of the work piece material is shown in below table.

Table 1: Work piece material properties

Cemented carbide(composition % by weight)		Transverse Rupture Strength (MPa)	Hardness HV 50	Density (gm/cm^3)	Thermal Conductivity (W/mK)	Coefficient of thermal expansion (K−1)
WC-94%	Co-6%	1900	1600	14.89	100	4.3 × 10−6

B. Tool material

In this work, the copper electrodes is selected in a round form with an area of Ø8mm × 40 mm in length. Copper is a common base material because it is highly conductive and strong. Copper electrode – it is one of the oldest and commonly preferred as tool material. Its melting point at 1083° C density= 8.9 gm/cm^3 and electrical resistivity of 0.0167 ohm mm^2/m, coefficient of expansion of 4.318 x 10^{-4} mm mm/K and its abundant availability is the reason behind its use.

C. Evaluation of MRR

The material MRR is expressed as the ratio of the difference of weight of the work piece before and after machining to the machining time and density of the material.

$$MRR= \frac{W_b - W_a}{t \times \rho}$$

Whereas

W_b = Weight of workpiece before machining.

W_a = Weight of workpiece after machining.

t = Machining time, ρ = Density of tungsten carbide =14.89gm/cm^3

D. Evaluation of tool wear rate

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time and density of the material. That can be explain this equations

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$$TWR = \frac{T_b - T_a}{t \times \rho}$$

Whereas
Tb = Weight of tool before machining.
Ta = Weight of tool after machining.
t = Machining time, ρ = Density of copper =8.9 gm/cm^3

E. Experimental set up-

For this experiment the whole work is done on Electric Discharge Machine, Model ELECTRONICA-ELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap) and positive polarity for electrode is used to conduct the experiments. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94°C) is used as dielectric fluid. Experiments are conducted with positive polarity of electrode. The pulsed discharge current is applied in various steps in positive mode. This Electrical discharge machine (EDM) is used to machine on for conducting the Experiments. This machine model ELECTRONICA-ELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap).

Figure 1- Die Sinker EDM Model: PS 50ZNC

IV. RESULTS AND DISCUSSION

A. Material removal Rate, MRR Analysis

According to figure2, it shows that the higher current will gives the higher the value of MRR of tungsten carbide. Figure3 shows that when the voltage is increased, the MRR will follow increased. Other than that, figure4 shows that the result of graph is when the pulse on time is increased, MRR will follow increase. The results obtained from the experimentation have been expressed in the form of graphs shown in figure 2-7.

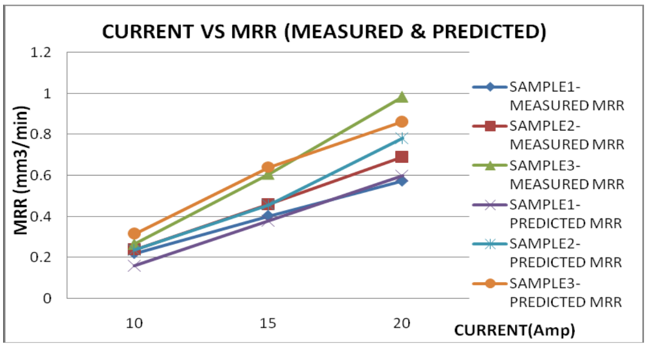

Figure 2- MRR (measured & predicted) Vs Current for 3 samples

Justification -

1) Measured and predicted MRR trend with respect to CURRENT.
2) Relative error between measured MRR and predicted MRR by regression analysis.
3) Increase in MRR with respect to CURRENT.

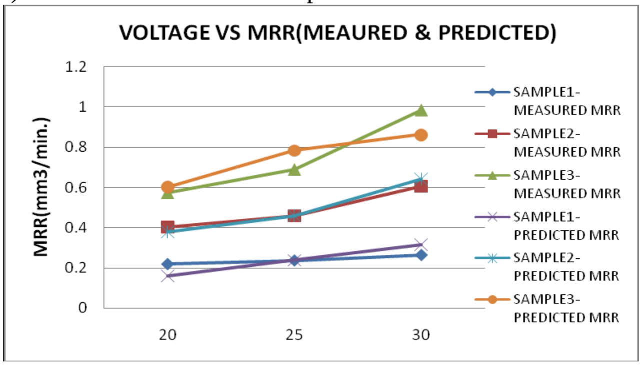

Figure 3- MRR (measured & predicted) Vs Voltage for 3 samples

Justification-

1) Measured and predicted MRR trend with respect to VOLTAGE.
2) Relative error between measured MRR and predicted MRR by regression analysis.
3) Increase in MRR with respect to VOLTAGE.

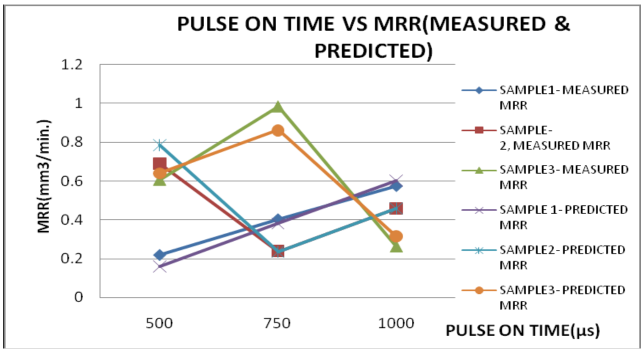

Figure 4- MRR (measured & predicted) Vs Pulse on time for 3 samples

Justification-

1) Measured and predicted MRR trend with respect to PULSE ON TIME.
2) Relative error between measured MRR and predicted MRR by regression analysis.
3) Increase in MRR with increase the PULSE ON TIME.

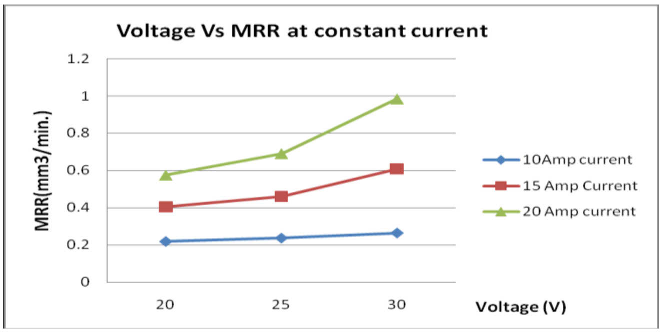

Figure 5- Voltage Vs MRR at constant Current

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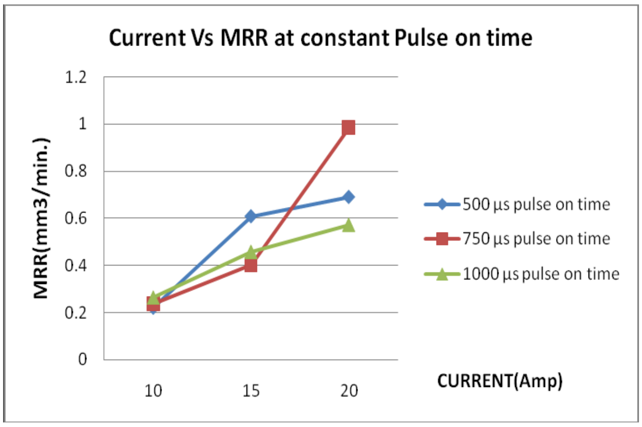

Figure 6- Current Vs MRR at constant Pulse on time

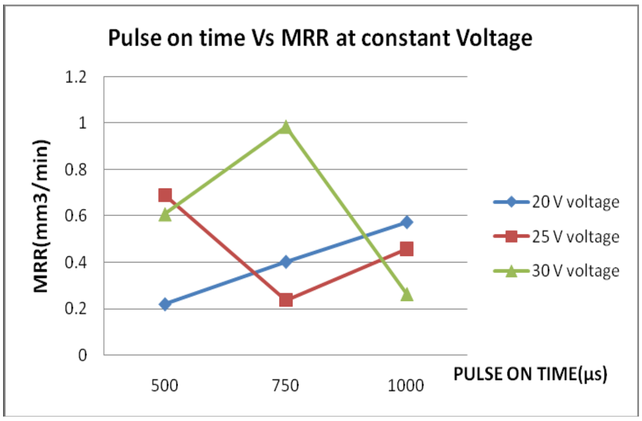

Figure 7- Pulse on time Vs MRR at constant VOLTAGE

B. Tool Wear Rate, TWR Analysis

According to figure 8, it shows that the higher current will gives the higher the value of TWR of tungsten carbide. Figure 9 shows that when the voltage is increased, the TWR will follow increased. Other than that, figure 10 shows that the result, when the pulse on time is increased, TWR will follow increase. The results obtained from the experimentation have been expressed in the form of tables and graphs shown in figures
8 to13.

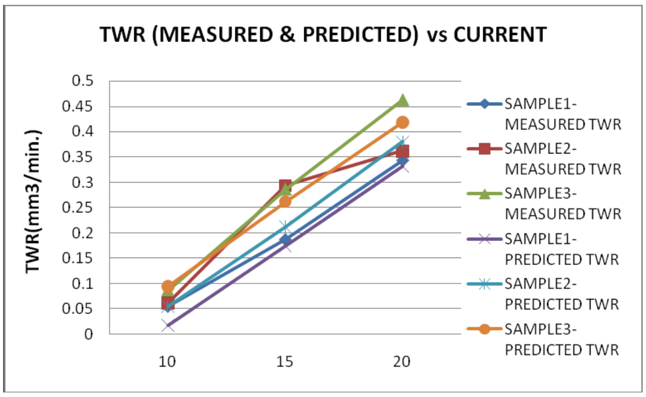

Figure 8- TWR (measured & predicted) Vs Current for 3 samples

Justification-

1) Measured and predicted TWR trend with respect to CURRENT.
2) Relative error between measured TWR and predicted TWR by regression analysis.
3) Increase in TWR with respect to CURRENT.

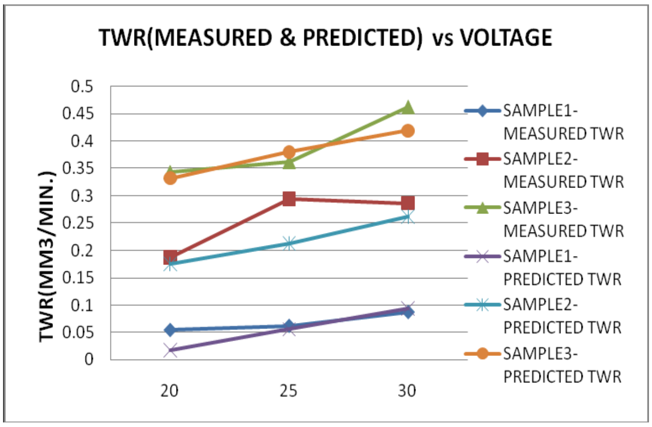

Figure 9- TWR (measured & predicted) Vs Voltage for 3 samples

Justification-

1) Measured and predicted TWR trend with respect to VOLTAGE.
2) Relative error between measured TWR and predicted TWR by regression analysis.
3) Increase in TWR with respect to VOLTAGE.

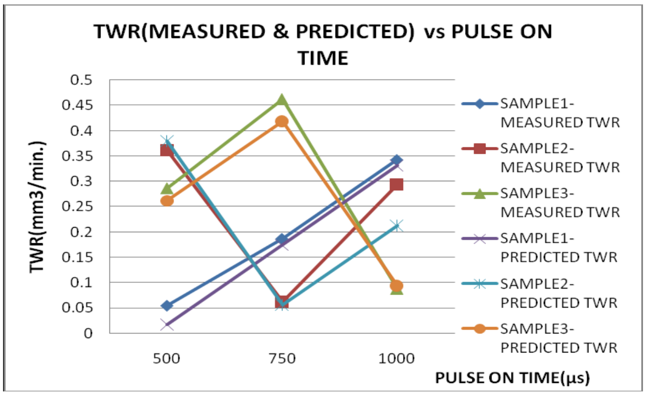

Figure 10- TWR (measured & predicted) Vs Pulse on time for 3 samples

Justification-

1) Measured and predicted TWR trend with respect to PULSE ON TIME.
2) Relative error between measured TWR and predicted TWR by regression analysis.
3) Increase in TWR increase the PULSE ON TIME.

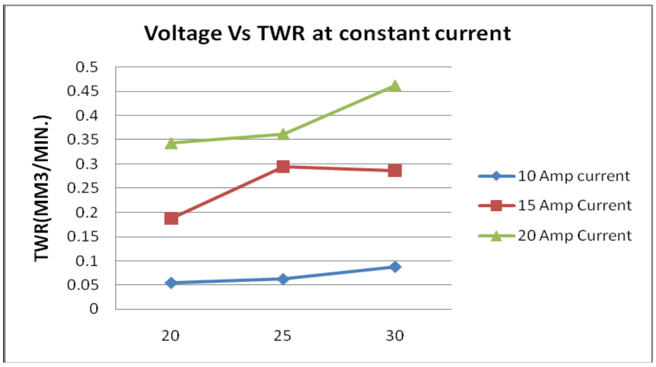

Figure 11- Voltage Vs TWR at constant Current

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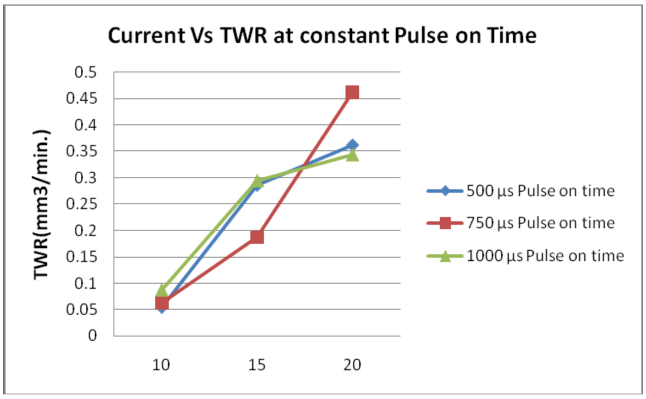

Figure 12- Current Vs TWR at constant Pulse on time

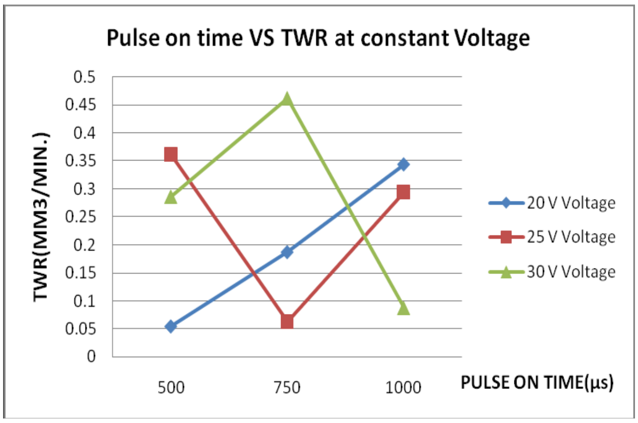

Figure 13- Pulse on time Vs TWR at constant VOLTAGE

V. CONCLUSION

Basically this investigation is successful achieved the objective with the acceptable outcome. This experiment evaluates the machining of Tungsten carbide with a Copper as Electrode. The Taguchi method Design of experiment (DOE) is very useful in the analyzing the optimum condition of parameters, main effect, and the significance of individual parameter to Material removal Rate and Tool Wear Rate. In case of material removal rate, it was seen that current factor was the most influential, followed by voltage and pulse on time. In order to obtain high material removal rate for the case of tungsten carbide, within the work interval considered in this study, one should use, high values for current and voltage. Finally, in case of tool wear rate, it was observed that the most influential were current, followed by voltage and pulse on time. Therefore, in order to be able to obtain low values of tool wear rate, low values of pulse on time, current and voltage.

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