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Parametric Study and Optimization of WEDM Parameters for Titanium diboride TiB_2

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Abstract - ***Wire electrical discharge machining (WEDM) is used in industry for machining complex profiles with high accuracy in conductive material. In the present work, the parametric optimization method using Taguchi method is proposed for WEDM of Titanium diboride TiB2 component. Three process parameters are selected for this investigation; Pulse on-time, Pulse off-time and wire feed. The experimentation is conducted by using Taguchi's L27 orthogonal array. Signal to Noise ratios of the Material removal rate, Surface roughness and Overcut for all experiments are calculated. The results are analyzed using analysis of variance (ANOVA) and response graphs and presented.***
Keywords: WEDM, Pulse on-time, Pulse off-time, TiB_2.

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1. INTRODUCTION

Electrical Discharge Machining (EDM) was first introduced in the 1940's as a crude device used to cut broken machining tools from expensive in-process parts. Since that time EDM has become a sophisticated and indispensable technology, revolutionizing the tool, die, and mold making industries, and making significant inroads into the production of highly accurate, intricate and difficult to machine production parts. In electrical discharge machining, it is important to select machining parameters for achieving optimal machining performance. Usually, the desired machining parameters are determined based on experience or handbook values. However, this does not ensure that the selected machining parameters result in optimal or near optimal machining performance for that particular electrical discharge machine and environment. The wire does not touch the work-piece, so there is no physical pressure imparted on the work- piece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the work-piece. The accuracy, surface finish and time required to complete a job is extremely predictable, making it much easier to quote; WEDM leaves a totally random pattern on the surface as compared to tooling marks left by milling cutters and grinding wheels. The WEDM process leaves no residual burrs on the work-piece, which reduces or eliminates the need for subsequent finishing operations. From the literature several researchers have been applied the Taguchi method to optimize the process parameters in WEDM process. In the Present work Titanium diboride TiB_2 is considered for measuring the output parameters like material removal rate, surface roughness and overcut using Taguchi method.

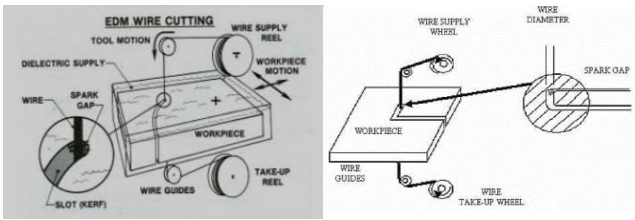

Fig -1: Schematic Representation of WEDM

2. EXPERIMENTAL DESIGN

Proper experimental design significantly contributes towards the accurate characterization and optimization of the process, in present work Taguchi L_{27} orthogonal experiments is used to study the influence of process parameters on MRR, OC and SR. In this study process parameters selected are Pulse-on Time (TON), Pulse-off time (T_{OFF}) and Wire feed rate (WF) whereas the Performance measures are: Material removal rate (MRR), Surface roughness (SR) and Overcut (OC).The work-piece selected for investigation of optimum setting for WEDM process is TiB_2. The chemical composition of TiB_2 is as shown in Table 1.

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Table -1: Chemical composition (in %)

Ti	B	N	Si	Fe	Ni
65.45	29.55	0.09	0.14	0.08	0.01

Controlled process parameters such as Pulse on time (T_{ON}), Pulse-off-time (T_{OFF}) and Wire Feed (WF) used in this study are shown in Table 2. Each factor is investigated at different levels to determine the optimum settings for the WEDM process. These parameters and their levels were chosen based on the review of literature and the few preliminary investigations. The other process parameters may have effect on measure of performance. To avoid these, the other process parameters are kept constant; Servo voltage 50V, Servo feed 2100, Peak current 230A, Peak voltage 2, Water pressure 0lpm, Wire tension 8gm. The smallest standard 3-level Orthogonal Array L_{27} is chosen.

Table -2: Control factors and their levels

Control factors	Unit	Level 1	Level 2	Level 3
Pulse-on time	µs	112	115	118
Pulse-off time	µs	42	45	48
Wire feed rate	mm/min	4	6	8

The parameters that were studied to determine the optimum setting for the WEDM process are as shown in Table 2.

Table No. 3 shows the twenty seven cutting experimental runs with the assigned levels of the process parameters according to the selected L_{27} orthogonal array.

Table -3: S/N ratios of MRR, SR and OC

Expt. No.	S/N ratios for MRR (gm/min)	S/N ratios for SR (µm)	S/N ratios for OC (mm)
1	-11.4929	-6.40293	16.1097
2	-11.626	-6.1926	16.3631
3	-11.3877	-5.80069	16.7427
4	-12.0131	-6.36127	17.6215
5	-12.5382	-6.0206	17.6546
6	-13.1085	-6.23508	17.6878
7	-15.1149	-5.97706	17.7211
8	-14.6382	-5.57507	17.7211
9	-14.3267	-5.66602	17.7882
10	-11.843	-6.23508	17.8219
11	-11.9806	-6.36127	17.8219
12	-12.197	-6.60828	17.8558
13	-13.0237	-6.68908	17.8898
14	-13.6654	-6.76913	17.8898
15	-13.8914	-6.68908	17.9239
16	-14.3344	-7.08217	17.9582
17	-14.7313	-6.76913	17.9582
18	-15.2213	-7.04365	17.9926
19	-12.7492	-7.1587	18.0271
20	-13.0093	-7.56796	18.0966
21	-13.3595	-7.60422	18.1316
22	-13.8996	-7.64034	18.1316
23	-14.4868	-7.42136	18.1316
24	-14.4599	-7.53154	18.1667
25	-13.905	-7.53154	18.2019
26	-15.2554	-7.38432	18.2373
27	-14.4131	-7.23456	18.2728

Table -4: Response table for S/N ratio for MRR (Higher the better)

Level	T_{ON}	T_{OFF}	W_F
1.	-13.22	-12.2485	-11.922
2.	-11.81	-11.574	-11.618
3.	-9.948	-11.1532	-11.436
Delta	3.2673	1.095267	0.4863

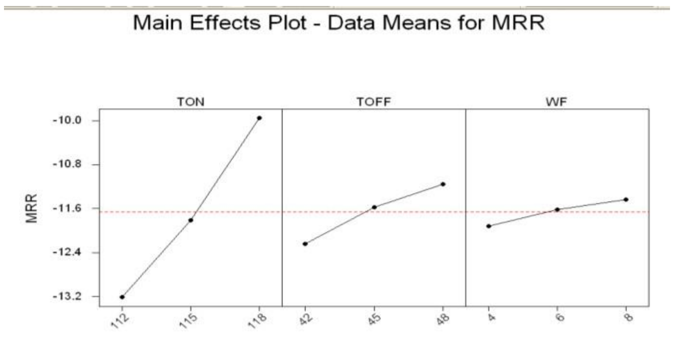

Fig -2: Main effect Plot of S/N ratios for Material Removal Rate

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In main effect plot of S/N ratio for material removal rate, x-Axis indicates different levels of process parameters and Y-Axis shows average of S/N ratio. It can be observed from Graph no.1 that material removal rate increase with increase in pulse-on time and pulse of time. Wire feed rate have very small effect on material removal rate.

Table No. 5: Response table for S/N ratio for SR (Lower the better)

Level	T_{ON}	T_{OFF}	W_F
1.	-6.026	-6.65908	-6.7865
2.	-6.694	-6.8175	-6.6735
3.	-7.453	-6.69595	-6.7126
Delta	1.427	0.158417	0.113
Rank	1	2	3

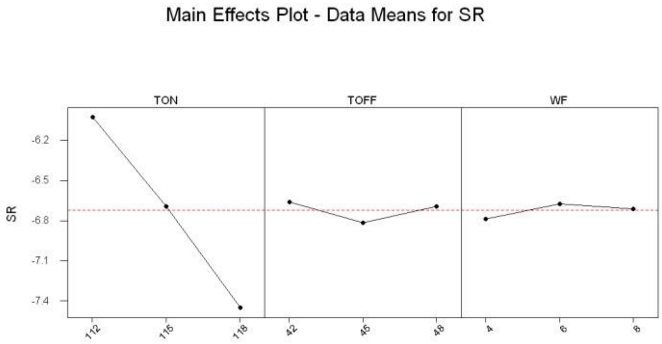

Fig -3: Main effect Plot of S/N ratios for surface roughness

In main effect plot S/N ratio for surface roughness, X-axes indicate different levels of process parameters and Y-axis shows average of S/N ratio. It can be observed from Graph no.2 that surface roughness decreases with decrease in pulse-on time. Pulse-off time and wire feed rate have very small effect on surface roughness.

Table No. 6: Response table for S/N ratio for OC (Lower the better)

Level	TON	TOFF	WF
1.	17.268	17.44117	17.717
2.	17.894	17.89213	17.76
3.	18.155	17.98349	17.84
Delta	0.8875	0.542317	0.1237
Rank	1	2	3

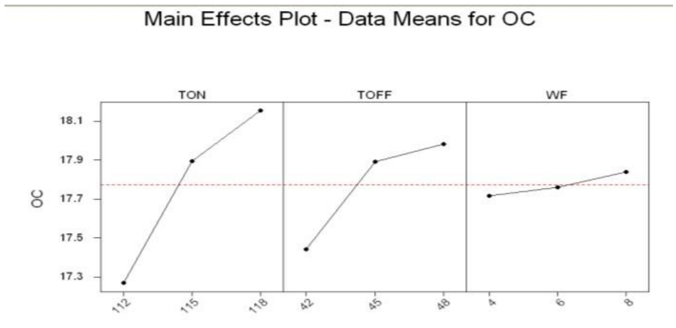

Fig -4: Main effect Plot of S/N ratios for overcut

In main effect plot of S/N ratio for overcut, X axis indicates different levels of process parameters and Y axis shows average of S/N ratio. It can be observed from given Graph no.3 that overcut increases with increase in pulse-off time and also increases with increasing in pulse-on time and wire fed rate has very small effect on overcut.

Table No. 7: Conformation of experiments for MRR

Optimal cutting parameters		
	Prediction	Experiment
Level	A3-B3-C3	
S/N ratio	-15.4080	-14.2171
MRR	0.1696	0.1946

Table No. 8: Conformation of experiments for SR

Optimal cutting parameters		
	Prediction	Experiment
Level	A1-B1-C2	
S/N ratio	-6.0012	-6.4444
SR	1.99	2.10

Table No. 9: Conformation of experiments for OC

Optimal cutting parameters		
	Prediction	Experiment
Level	A3-B3-C3	
S/N ratio	18.5604	18.6735
OC	-0.1180	-0.1165

Comparison between actual experimented values and RSM prediction values. Result obtained from RSM method and experimented method should be validated. Results obtained from both experimented values and RSM prediction values are cross checked with each other. Finally residual error between then is found out.

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Table No. 10: Comparison between actual and RSM values for MRR, OC

Performance Measures	Actual	Predicted	Residual Error	% Error
MRR	0.1946	0.1696	0.025	14.74
SR	2.10	1.99	0.11	5.53
OC	-0.1165	-0.1180	-0.0015	1.27

3. CONCLUSIONS

The effect of pulse-on time, pulse-off time and wire feed are investigated in machining of TiB2 by keeping other process parameters constant. Use of the Taguchi method for the optimization of the wire-cut electric discharge machining process is demonstrated in this work. Based on the experimental results, the conclusions can be drawn as follows.

1. The Pulse-on time and pulse-off time are most significant whereas wire feed rate is insignificant for material removal rate. Response table for MRR indicate that pulse-on time has most effect on MRR followed by pulse-on time and wire feed rate. For maximum MRR, the recommended parametric combination is A3-B3-C3.
2. Response table for SR indicate that pulse-off time has most significant effect on SR follow by pulse-on time and wire feed rate. For better surface finish, the recommended parametric combination is A1-B1-C2.
3. Response table for OC indicate that pulse-off time has most effect on SR followed by pulse-on time and wire feed rate. For minimum OC, the recommended parametric combination is A3-B3-C3. The approach used in this study can be used for other material like steel and aluminium. The effect of thickness of material on output can be studied by using work piece material of different thickness.

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