Research Article

Experimental Investigation on Material Removal Rate (MRR) and Kerf Width in WEDM by Taguchi Method

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Abstract

This paper presents an effect of different process parameters on material removal rate (MRR) and kerf width in wire electrical discharge machining (WEDM). Die steel AISI D3 is used for experimental purpose due to its good mechanical and tribological properties. In this study, the experiments were designed by Taguchi method using L9 orthogonal array. The process parameters like Pulse on time, pulse off time and wire feed rate were selected as input process parameters to analyze output quality characteristics in terms of material removal rate and kerf width. Analysis of variance (ANOVA) is carried out to demonstrate significant influence of input parameters on quality characteristics. The experimental results reveals that pulse on time is significant factor affects the MRR and kerf width.

Keywords: WEDM, ANOVA, Taguchi method, Material removal rate, Kerf width

Introduction

Wire electrical discharge machining is a spark erosion process used to machine conductive materials. During machining, the spark is produced between wire electrode and work piece immersed in dielectric fluid. From the recent years, die steel AISI D3 have gained advantages in lots of industrial application due to its good mechanical and tribological properties. Machining of this material is difficult with traditional methods due to tool failure and other loses, so WEDM is ideal machining process to deal with difficult to machine materials[1] Several researchers have reported their work on WEDM to improve quality characteristics like surface roughness, MRR, cutting speed and dimensional deviation. Scott et al. [2] reported surface finish and MRR in machining of die steel D2 by empirical model. Miller et al. [3] analyzed effect of spark cycle and pulse off time on various output characteristics during machining of carbon- carbon bipolar plates. Many researchers have reported their work on machining of die steel AISI D3 by various processes. Haddad and Tehrani [4] studied cylindrical wire electrical discharge turning of D3 with output quality characteristics like MRR, surface roughness and roundness. Camuscu and Aslan [5] reported milling of die steel D3 by using different tools, it revelaled that carbon boron nitride (CBN) tool give superior performance in terms tool life and surface characteristics. In other work, Aouici et al. [6] studied turning of die steel by using ceramic tool. Siller et al. [7] observed large amount of tool failures during milling of die steel AISI D3. This leads to increase in production cost due to increase in tool cost. Based on these studies, it revealed that machining of die steel AISI D3 is expensive and difficult due to tool failure. There are number of research articles available on WEDM of various materials with different optimization techniques.

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Tzeng et al. [8] reported machining of tungsten by WEDM, it revealed that pulse on time is most significant parameter that will influence MRR. Jangra et al. [9] studied machining of tungsten carbide composite by WEDM with graph theoretic approach. Golshan et al. [10] predicted performance of zinc and brass wire in WEDM. In other study, Singh et al. [11] successfully implemented L9 orthogonal array during drilling of metal matrix composite.

Experimental Setup and Equipments

In this study, experiments were performed on Electronica Ecocut Elplus 15 wire EDM machine. The specimens consider for machining is die steel AISI D3. The chemical composition of die steel AISI D3 used for experimentation follow as : C(1.56%), Si(0.33%), Mn(0.61%), P(0.02%), S(0.04%), Cr(13.4%), Co(0.01%), Ni(0.10%) and Fe(83.93%). Experimentation conditions for WEDM are shown in Table 1.

Table 1 WEDM experimentation conditions

Work piece	AISID3 (150mm×150mm×10m
Tool Electrode	Brass wire (ɸ 0.25 mm)
Dielectric medium	Deionized water
Pulse on time (µs)	0.70, 0.80, 0.90
Pulse off time (µs)	30,34,38
Wire feed rate (m/min)	5,7,9

During each experiment a punch of size 5mm× 5mm× 10mm was cut into work piece with brass wire electrode of 0.25 mm diameter. The dimensions of machined samples were measured by digital micrometer Mitutoyo having least count of 0.001 mm.

Design Of Experiment (DOE) and Experimental Results

DOE is utilized for minimizing the number of experiments with superior results. Taguchi method with L9 orthogonal array was chosen to carry out the experimental study. Three factors i.e. pulse on time (A), pulse off time (B) and wire feed rate (C) with three different levels were taken as input parameters shown in Table 2.

The input parameter and their levels were selected on the basis of pilot experimentation i.e by one factor at time (OFAT) approach. Material removal rate and kerf width were observed as output quality characteristics in this experimental work.

Table 2 Input parameters with their levels

Symbols	Process parameters	Level 1	Level 2	Level 3
A	Pulse on time(µs)	0.70	0.80	0.90
B	Pulse off time (µs)	30	34	38
C	Wire feed rate(m/min)	5	7	9

The other factors of WEDM like spark gap set voltage, wire tension, peak current and flushing pressure remains constant during this research work.

Quantitative data of machining for die steel AISI D3 work piece are shown in table 3.

Table 3 Quantitative data of WEDM experiments (Non treated work piece)

Experiment no.	Pulse on time	Pulse off time	Wire feed rate	Material removal rate (mm^3/min)		Kerf Width (mm)	
				MRR	S/N Ratio	Kerf Width	S/N Ratio
1	0.7	30	5	1.250	1.93820	0.293	10.6626
2	0.7	34	7	1.123	1.00760	0.285	10.9031
3	0.7	38	9	0.673	-3.43970	0.280	11.0568
4	0.8	30	7	1.975	5.91134	0.350	9.1186
5	0.8	34	9	1.523	3.65400	0.332	9.5772
6	0.8	38	5	1.236	1.84037	0.310	10.1728
7	0.9	30	9	2.863	9.13643	0.401	7.9371
8	0.9	34	5	2.015	6.08550	0.382	8.3587
9	0.9	38	7	1.720	4.71057	0.361	8.8499

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Analysis and Discussion of Results

Material removal rate

Material removal rate is amount of material removal per unit time during machining,; it is measured in mm^3/min. The detailed data of MRR for different experiments of WEDM are shown in Table 3, MRR is calculated by using Eq. 1

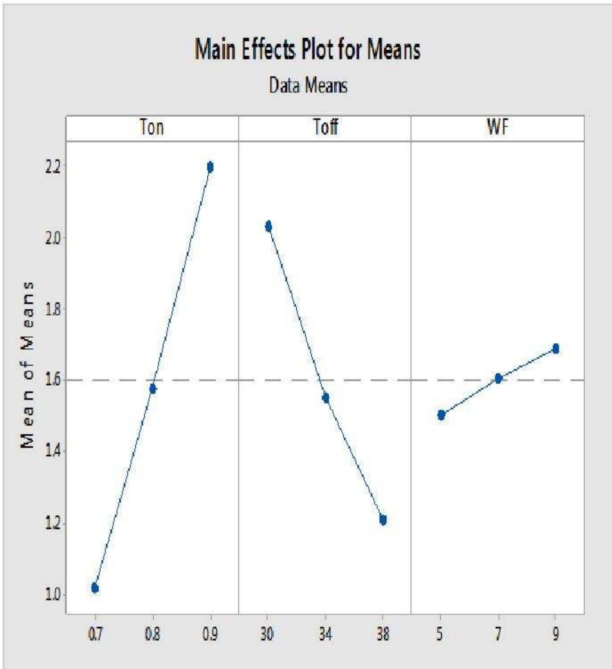
MRR=Cutting speed× height of workpiece× width of cut………… (1)

Table 4 represents the ANOVA results for MRR, it revealed that pulse on time is most significant factor affecting the MRR with percentage contribution of 65 %. Additionally, pulse off time is secondly momentous factor affects the MRR with percentage contribution of 35 %. The effect of other factor i.e wire feed rate remains negligible on MRR. Figure 1 reveals effect of different process parameters on MRR. It observed that with increase in pulse on time MRR increases linearly due to increase in discharge energy. MRR is found to be decreases with increase in value of pulse off time. It occurs due to decrease in intensity of sparking. The effect of wire feed rate remains negligible because it does not affect discharge energy during machining.

Table 4 ANOVA results for MRR

Source	DOF	Adj SS	Adj MS	F	P	Percentage contribution
Pulse on time	2	2.10450	1.05225	21.70	0.044*	65
Pulse off time	2	1.01645	0.50822	10.48	0.087	30
Wire feed rate	2	0.05221	0.02611	0.54	0.650	2
Error	2	0.09698	0.04849			3
Total	8	3.27015				

Significant at 95 % Confidence Level



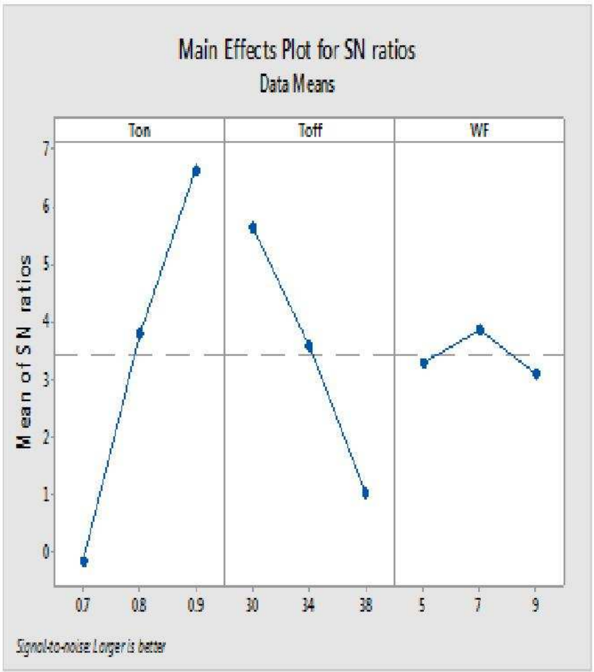


Figure 1.Effect of different process parameters on MRR
(a) Plot for mean data of MRR (b) Plot for S/N ratio of MRR

Kerf Width

Kerf width is the width of machined slot measured by Nikon profile projector. The kerf width is average of five value of kerf width calculated from different points of cut. It is measured in mm, it also represents the amount of material wasted during machining and dimensional accuracy of machined part. Analysis of variance shows that pulse on time is mostly momentous factor affects the kerf width with percentage contribution of 88 %. The other factors pulse off time and wire feed rate remains less significant. Figure 2 reveals effect of process parameters on kerf width, it shows that kerf width increases linearly with increase in pulse on time. It occurs due to increase in amount of sparking which tends to side erosion of material. Similarly, with increase in pulse off time kerf width decreases due to decrease in discharge energy.

Table 5 ANOVA results for Kerf Width

Source	DOF	Adj SS	Adj MS	F	P	Percentage contribution
Pulse on time	2	0.013651	0.006825	119.05	0.008*	88
Pulse off time	2	0.001442	0.000721	12.58	0.074	9
Wire feed rate	2	0.000133	0.000066	1.16	0.464	1
Error	2	0.000115	0.000057			2
Total	8	0.015340				

Significant at 95 % Confidence Level

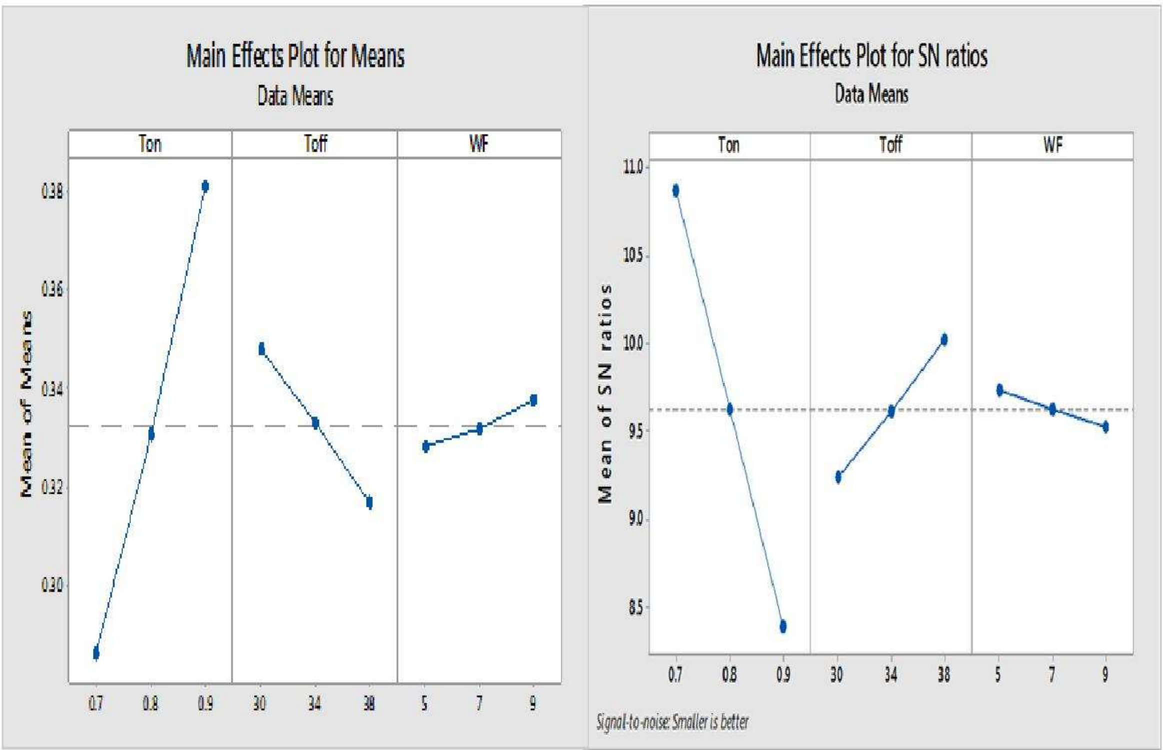


Figure 2: Effect of process parameters on kerf width (a) Plot for mean data of kerf width (b) Plot for S/N ratio of kerf width

Conclusions

1. ANOVA results reveals that MRR is significantly affected by pulse on time while other factors like pulse off time and wire feed rate remains less significant.
2. MRR is momentously influenced by pulse on time with percentage contribution of 65 %. It occurs due to increase in amount of amount of discharge energy during machining.
3. In kerf width quality characteristics ANOVA shows that pulse on time is most significant factor with percentage contribution of 88 %.
4. With increase in value of pulse off time the MRR and kerf width decreases significantly due to reduction in discharge energy.
5. The effect of wire feed rate on MRR and kerf width remains negligible because it does not affect discharge energy during machining.

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