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Analysis of Quality and Productivity in Wire Electrical Discharge Machining (WEDM)

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Abstract— an experimental investigation was conducted to determine the main machining parameters which contribute to material removal rate (MRR) and surface roughness (SR) in wire-EDM of mild steel. In WEDM operations, material removal rate determine the economics of machining and rate of production that is overall productivity and surface roughness is the measure of quality. Proper selection of process parameters is essential to obtain good surface finish and higher MRR. In setting the machining parameters, particularly in rough cutting operation, the goal is - the maximization of MRR means productivity, minimization of SR or increasing the quality. In this experiment using the selected control parameters are discharge current, pulse on time, pulse off time and servo feed setting. The four control parameters each are three level means L_{27} orthogonal array based on Taguchi design is selected for this analysis. The relatively significant parameters were determined by Analysis of Variance (ANOVA). The variation of output responses with process parameters were mathematically modeled by using non-linear regression analysis. The models were checked for their adequacy.

Keywords: Material removal rate (MRR), Surface roughness (SR), ANOVA, Taguchi Design, Quality, Productivity.

1. INTRODUCTION

The non-traditional manufacturing process of wire-electrical discharge machining (WEDM) possesses many advantages over traditional machining during the manufacture of Mild Steel parts.WEDM is mostly used to cut difficult-to-machine materials and high asset temperature resistant alloys. It is the most widely and effectively useful machining process for various work piece materials [1].With a view to alleviate this trouble, various surveys have been carried out by several researchers for improving selection of optimal parametric values for the MRR, Surface Finish [2–6]. However, the problem of selection of machining parameters is not fully depending on machine controls rather material dependent. To advance manufacturing processes with single performance characteristic, the optimal selection of control parameters Taguchi method has been widely adopted. Traditional Taguchi method cannot solve multi-objective optimization problems. To overcome this, the Taguchi method together with Grey relational analysis (GRA) has a wide area of application in manufacturing processes and other optimization process[7– 12].The objective of the present work is an attempt to finding feasibility of machining Mild Steel using copper electrode wire. The machining parameter selected for discharge current, pulse on time, pulse off time and servo feed using L_{27} orthogonal array based on Taguchi design approach analyzing the responses MRR and SR.

2. EXPERIMENTATION

Wire EDM machine puts impulse voltage between electrode wire and work piece through impulse source, controlled by servo system, to get a certain gap, and realize impulse discharging in the working liquid between electrode wire and work piece. Numerous tiny holes appear due to erosion of impulse discharging, and therefore get the needed shape of work piece (Shown in Fig. 1).For this experiment the whole work can be down by Wire Electric Discharge Machining, model Electronica EZEECUT-WEDM with servo-head (constant gap) and positive polarity for electrode was used to conduct the experiments. Distil water as a dielectric fluid, with side flushing of copper tool. Experiments were conducted with positive polarity of electrode.

Fig 1. Wire Electric Discharge Machining

3. TAGUCHI DESIGN EXPERIMENTS IN MINITAB

Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. Taguchi proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two, three, four, five, and mixed-level fractional factorial designs. Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes. In the experiment using four factors and each are three levels then total number of experiments to be conducted is 27. In this study, an L_{27} OA based on Taguchi design are used machining parameters like discharge current, pulse on time, pulse off time and servo feed setting were varied to conduct 27 different experiments and the measurements weights of the work piece were taken for calculation of MRR. Minitab software was used to analysis the findings.The levels of experiment parameters are like discharge current, pulse on time, pulse off time and servo feed setting shown in Table 1 and the Response are depicted in Table 2.

Table 1 Machining parameter and their levels

Parameters	unit	Level 1	Level 2	Level3
Ip (Discharge Current)	A	13	18	23
T_{on} (pulse on time)	(µs)	100	112	118
T_{off} (pulse off time)	(µs)	20	30	40
SF (Servo Feed)	(mm/µ)	500	1300	2000

Table 2 Observation table

SR. No.	Ip (A)	Ton (µs)	Toff (µs)	SF(mm/µ)	MRR (mm^3/min)	SR (µm)
1	13	100	20	500	0.004007	0.780
2	13	100	20	500	0.004942	0.660
3	13	100	20	500	0.021047	0.840
4	13	112	30	1300	0.002890	0.950
5	13	112	30	1300	0.014226	0.450
6	13	112	30	1300	0.208397	0.850
7	13	118	40	2000	0.016429	1.082
8	13	118	40	2000	0.089343	1.195
9	13	118	40	2000	0.045526	0.980
10	18	100	30	2000	0.119816	1.050
11	18	100	30	2000	0.145985	1.010
12	18	100	30	2000	0.093458	1.030
13	18	112	40	500	0.032222	0.930
14	18	112	40	500	0.225000	1.040
15	18	112	40	500	0.217054	1.000
16	18	118	20	1300	0.225000	1.300
17	18	118	20	1300	0.065116	0.950
18	18	118	20	1300	0.538462	0.930
19	23	100	40	1300	0.500000	1.220
20	23	100	40	1300	0.259259	1.370
21	23	100	40	1300	0.114537	1.000
22	23	112	20	2000	0.547170	1.137
23	23	112	20	2000	0.551020	1.820
24	23	112	20	2000	0.787234	1.710
25	23	118	30	500	0.201923	1.030
26	23	118	30	500	0.551020	0.910
27	23	118	30	500	0.787234	1.030

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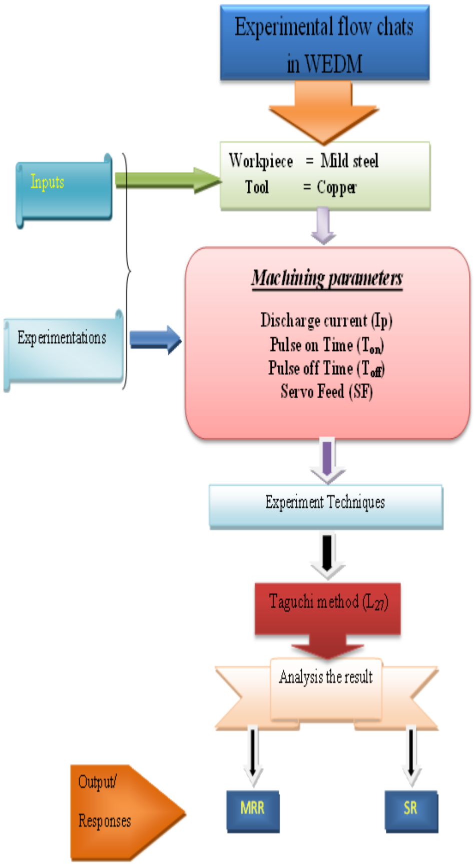
4. FLOW CHART OF EXPERIMENT



5. RESULT AND DISCUSSIONS

In This chapter are related about influences of MRR and SR in WEDM and finding the result which factors discharge current, pulse on time, pulse off time and servo feed of Copper tool, is most with mild steel work piece important with help of orthogonal array based on Taguchi L_{27} design.

5.1 INFLUENCES ON WEDM PARAMETERS ON MRR

The effects of several machining parameters likes Ip, T_{on}, T_{off}, and SF on MRR are shown in Fig. 2. This figure describes that discharge current (Ip) is directly proportional to MRR. This is expected because an increase in pulse current produces more sparks, which produces the greater temperature, causing more material to melt and erode from the work piece. Besides, it is evident that the other factors did not influence MRR much when compared to Ip[13]. MRR increased with T_{on} from 110 µs to 118 µs. As the pulse-on time increases, the total energy supply to the workpiece is more, so more material is eroded from workpiece [14-15].MRR slightly increasing with increase in pulse off time and servo feed is not significantly affected the MRR according the Analysis of variance table. In the table that are shown in Table 3 and this table indicts the columns characterize sources of variation, Degrees of Freedom (DF), Sequential Sum of Squares (Seq SS), Mean of Squares (MS), statistic F and P.

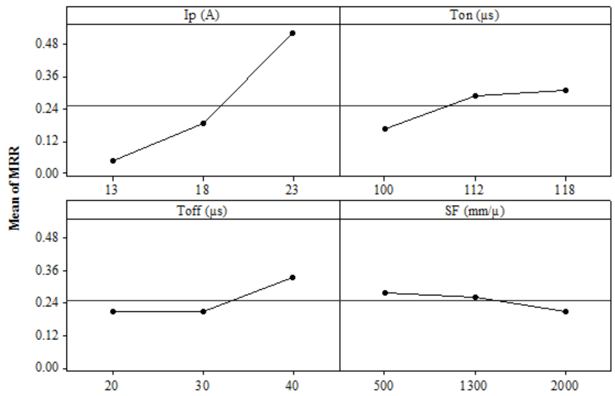


Fig. 2 Main effect plots for MRR

Table 3 Analysis of Variance for MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ip (A)	2	1.08260	1.08260	0.54130	38.86	0.000
T_{on} (µs)	2	0.10896	0.10896	0.05448	3.91	0.039
T_{off} (µs)	2	0.09550	0.09550	0.04775	3.43	0.055
SF (mm/µ)	2	0.02607	0.02607	0.01304	0.94	0.411
Residual Error	18	0.25076	0.25076	0.01393		
Total	26	1.56389				

In the analysis of variation of define different parameters effects and the column P is indicating the probability of acceptances if our confidence levels is 95 %. According to this rules the value of column P is greater than 0.05, those parameters is not significantly affected. So the table 3 indicates SF is not significantly affected. But other parameters are affected significantly. Table 4 indicates which factor is more important as compare to other parameters. According to this table Ip is more important than T_{on}, T_{off} and SF important respectively.

Table 4 Response Table for Means

Level	Ip (A)	Ton (µs)	Toff (µs)	SF (mm/µ)
1	0.04628	0.16256	0.20772	0.28244
2	0.18579	0.28725	0.21177	0.26371
3	0.52327	0.30553	0.33585	0.20918
Delta	0.47698	0.14297	0.12814	0.07326
Rank	1	2	3	4

5.2 INFLUENCES ON WEDM PARAMETERS ON SR

The main effect plots of SR are shown in Fig. 3. This figure indicates that discharge current has the most important influence as compared to other factors, because higher pulse current causes more energy to be released for melting leading to formation of cracks and hence resulting a poor surface finish. When pulse-on time is increasing SR increases up to a maximum level then it starts to decrease slightly. As the pulse-on time increases, the total energy supplied to the work piece is more, so more material is eroded from the surface of work piece resulting in increase of SR. But with higher pulse-on time, the plasma formed between the inter electrode gap hinders energy transfer thus small craters are formed, so SR reduces. Pulse off time and servo feed system is not significantly affected the surface finish.

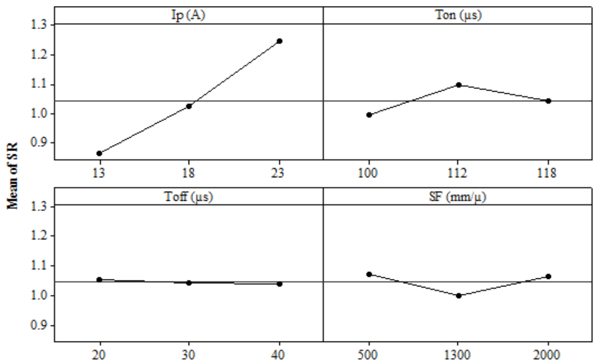


Fig. 3 Main effect plots for SR

MRR increased with Ton from 110 µs to 118 µs. As the pulse-on time increases, the total energy supply to the work piece is more, so more material is eroded from work piece. The analysis of variances Table 5 is indicates the Ip is significantly affected and other factors is not affected the SR. Table 6 shown the response table for SR according to this table Ip is more important than T_{on}, T_{off} and SF important respectively.

Table 5 Analysis of Variance for SR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ip (A)	2	0.66270	0.66270	0.331351	4.73	0.022
Ton (µs)	2	0.04776	0.04776	0.023880	0.34	0.716
Toff (µs)	2	0.00069	0.00069	0.000344	0.00	0.995
SF (mm/µ)	2	0.02984	0.02984	0.014918	0.21	0.810
Residual Error	18	1.26089	1.26089	0.070049		
Total	26	2.00188				

Table 6 Response Table for Means

Level	Ip (A)	Ton (µs)	Toff (µs)	SF (mm/µ)
1	0.8652	0.9956	1.0532	1.0739
2	1.0267	1.0986	1.0450	0.9997
3	1.2474	1.0452	1.0411	1.0658
Delta	0.3822	0.1030	0.0121	0.0742
Rank	1	2	3	4

6. CONCLUSIONS

L_{27} OA based Taguchi design was used to study MRR and SRon Mild tool steel with side impulse flushing. MRR is affected by T_{on} and T_{off}. It decreases and slightly increases with T_{on}.

The following conclusions are described.

- Finding the result of MRR discharge current is most influencing factor and then pulse duration time and the last is pulse off time than servo feed. MRR increased with the discharge current (Ip).

- In the case of surface roughness the most important factor of discharge current then pulse on time, pulse off time and other factors are not important as compare to this factors.

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