Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 3, March -2015

A multi-objective Optimization of Machining Characteristics in Wire Electrical Discharge Machining of P20 steel

N G Parmar[1], B.D.Parmar[2]

[1]*Mechanical Engg Deptt. Govt.Polytechnic, Kheda*
[2] *Mechanical Engg Deptt. Govt.Polytechnic, Porbandar*

Abstract : *Wire EDM machines are used to cut all conductive material of any hardness or toughness or those are difficult or impossible to cut with conventional methods. Wire electrical discharge machining process is a highly complex, time varying & stochastic process. In the present research, experimental investigations have been conducted to establish relationship of Material Removal Rate, surface finish and kerf width with current, pulse-ON and pulse-OFF time. Molybdenum wires of diameters 0.18 mm were used. Material tested is P20 steel material. Today, the most effective machining strategy is determined by identifying the different factors affecting the WEDM process and seeking the different ways of obtaining the optimal machining condition and performance. Result of confirmation experiments shows that the MRR increases with current and pulse on-time but machined surface becomes rougher and MRR decreases with increase in pulse-OFF time. The study demonstrates that the WEDM process parameters can be adjusted to achieve better metal removal rate, surface finish and cutting width simultaneously.*

Keywords*- WEDM. Metal removal rate, Surface finish, Kerf width, Taguchi Method.*

I.INTRODUCTION

Electrical discharge machining is a machining method primarily used for hard metals or those that would be very difficult to machine with traditional techniques. EDM typically works with materials that are electrically conductive. EDM can cut intricate contours or cavities in pre-hardened steel without the need for heat treatment to soften and re-harden them. This method can be used with any other metal or metal alloy such as titanium, hastelloy. Also, applications of this process to shape polycrystalline diamond tools have been reported Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. At present, WEDM is a widespread technique used in industry for high-precision machining of all types of conductive materials such as metals, metallic alloys, graphite, of any hardness [1]. The selection of optimum machining parameters in WEDM is an important step. Improperly selected parameters may result in serious problems like lower MRR,short-circuiting of wire, wire breakage and work surface damage which is imposing certain limits on the production schedule and also reducing productivity. As Material Removal Rate (MRR), Surface Roughness (Ra) and kerf width (k) are most important responses in WEDM; various investigations have been carried out by several researchers for improving the MRR, Surface Finish and kerf width [2]. However, the problem of selection of machining parameters is not fully depending on machine controls rather material dependent. For the optimal selection of process parameters, the Taguchi method has been extensively adopted in manufacturing to improve processes with single performance characteristic [3]. Mahapatra[4] studied the relationships between various control factors and responses like MRR, SF and kerf by means of nonlinear regression analysis, resulting in a valid mathematical model. Finally, genetic algorithm, a popular evolutionary approach, is employed to optimize the wire electrical discharge machining process with multiple objectives. The study demonstrates that the WEDM process parameters can be adjusted to achieve better metal removal rate, surface finish and cutting width simultaneously.

II.EXPERIMENTAL SETUP

The experiments were performed on Reusable type CNC WEDM, manufactured by Jiang nan saitec NC Co. Ltd. The machine is having mechanism for recirculation of wire wounded on drum. The electrode material used was a 0.18 mm diameter molybdenum wire. The high energy density erodes material from both the wire and work piece by local melting and vaporizing. The di-electric fluid (de-ionized water) is continuously flashed through the gap along the wire, to the sparking area to remove the debris produced during the erosion.15mm long cut were performed for each experimental run and time was observed to calculate MRR.

.

2.1 Work material

P20 steel having 15 mm thickness was used for the present investigation. The table 1 shows the chemical composition of P20 material. Chromium and nickel are the main alloying elements found in group P steels. The presence of chromium and nickel enhances the toughness and hardness of P20 steels. P20 tool steels are nitrided or carburized. These steels are capable of being machined into complex and large dies and molds. P20 steels are mostly used in the carburized condition. P20 tool steels are used for low temperature applications that include injection molds and die casting dies. It is Plastic mould steel which is generally pre-hardened to 29 – 33HRC, hence not convenient to machine with conventional HSS cutting tools. So, wire cut EDM is one of the most suitable machining operations. Equivalent materials to P20 tool steels are ASTM A681, UNS T51620, and DIN 1.2330.

Table 1. Chemical composition of work material

Chemical composition Wt%	C	Mn	Si	Cr	Mo	Cu	P	S
	0.28-0.40	0.60-1.00	0.20-0.80	1.40-2.00	0.30-0.55	0.25	0.03	0.03

2.2. Process parameters

For the present experimental investigation, Peak Current (A), Pulse-on time (B) and Pulse-off-time (C) are chosen as input process parameters.

Table 2. Process parameters

Dielectric	De-ionized water
Dielectric conductivity	38 mohs
Wire Tension	900 grams
Wire velocity	11.2 m/s
Wire diameter	0.18 mm
Wire material	Molybdenum
Workpiece material	P20
Workpiece thickness	15 mm
Workpiece hardness	30 HRc

These parameters and their levels were chosen based on the review of literature, experience, significance and their relevance as per the few preliminary pilot investigations. The standard 3-level Orthogonal Array L9 is chosen for this case.

2.3. Selection of Orthogonal array

The effect of many different parameters on the performance characteristic in a condensed set of experiments can be examined by using the orthogonal array experimental design proposed by Taguchi. Once the parameters affecting a process that can be controlled have been determined, the levels at which these parameters should be varied must be determined. The optimal process parameters are determined by analyzing the characteristic data acquired by using Orthogonal Arrays (OA). The total number of degrees needs to be computed to select an appropriate orthogonal array for the experiments.

Table 3. Orthogonal array

Symbol	**Control Factors**	**Unit**	**Level 1**	**Level 2**	**Level 3**
A	Current	Amp	3	5	7
B	Pulse-on Time	μs	16	32	48
C	Pulse-off Time	μs	4	8	12

The degrees of freedom are defined, as the number of comparisons that needs to be made to determine which level is better [9]. Since each three-level parameter has two degrees of freedom (number of levels-1), the degrees of freedom (DOF) required for three parameters, each at three levels, is 6 (3 x (3-1)). Hence an L9 OA was selected for this study. The layout of this L9-OA is shown in Table 2. Table 4 shows the nine experimental runs with the assigned levels of the process parameters according to the selected L9 orthogonal layout.

Table 4. Observations in Experiments

Exp. No.	Control Factors			Time	MRR	SR(Ra)	Kerf
	Current	T-on	T-off	Min	mm^3/min	μm	mm
1	3	16	4	14.00	3.776	2.51	0.235
2	3	32	8	14.36	3.775	2.62	0.241
3	3	48	12	19.81	2.737	2.58	0.241
4	5	16	8	9.67	5.492	2.21	0.236
5	5	32	12	12.84	4.310	2.91	0.246
6	5	48	4	6.22	9.339	2.92	0.258

7	7	16	12	16.38	3.310	2.38	0.241
8	7	32	4	4.47	13.190	2.90	0.262
9	7	48	8	4.51	13.385	3.39	0.268

In this study most important output performances in WEDM such as Material Removal Rate (MRR), Surface Roughness (Ra) and kerf width (k) were considered for optimizing machining parameters. The surface finish value (in µm) was obtained by measuring the mean absolute deviation, Ra (surface roughness) from the average surface level using a Computer controlled zeiss surface roughness tester. The Kerf width was measured using the profile projector. The Material Removal Rate (MRR) is calculated as,

$$MRR = k\ t\ v \quad \text{mm3/min}$$

Where, k is the Kerf width (mm), t is the thickness of work piece (mm) and v is the Cutting speed (mm/min).The cutting speed has been evaluated under each cutting condition by dividing the cutting length with the required cutting time.

III ANALYSIS OF RESULTS

The well known Taguchi technique is chosen and adopted in the present research work. In order to reduce the total number of experiments "Sir Ronald Fisher" has developed the solution: "Orthogonal Arrays". The orthogonal array is a distillation mechanism by which the engineers can select the experimental process. In the Taguchi method, a loss function has been defined to gauge the deviation between the experimental value and desired value of a performance characteristic. The loss function is further transformed into a signal-to-noise ratio (S/N ratio) [5, 6]. Three categories of performance characteristics are usually used in the analysis of the S/N ratio, i.e., the lower-the-better, the higher-the-better, and the nominal-the-best. In this analysis, the higher MRR and lower surface roughness and cutting width are the indication of better performance. The analysis was made using the software MINITAB 16, specifically used for design of experiment applications. Fig. 1-3 shows the effect of control factor on measured performance.

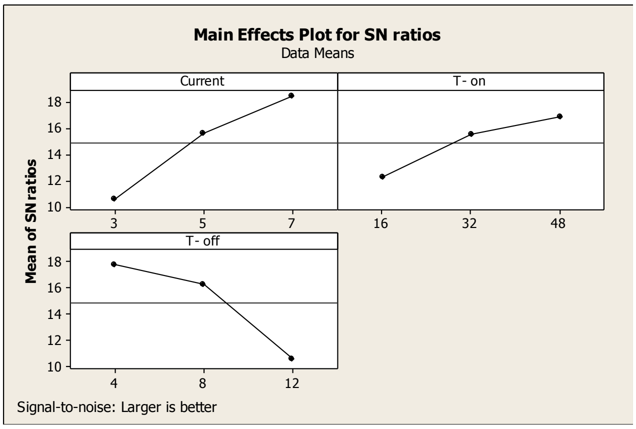

Fig.1 Effect of control Factors on MRR

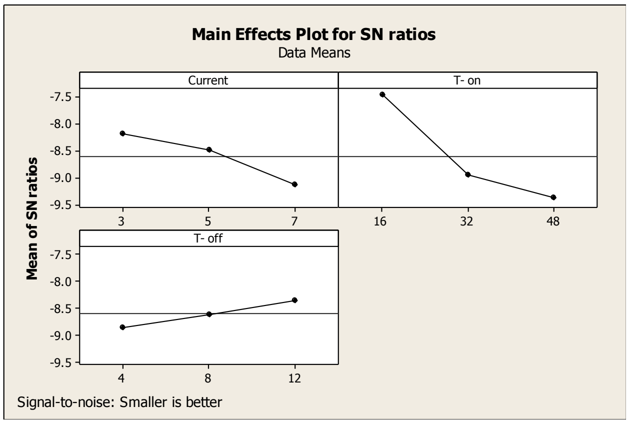

Fig.2 Effect of control Factors on SR

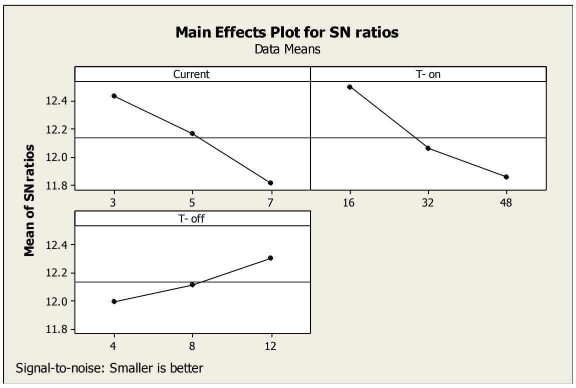

Fig.3 Effect of control Factors on Kerf Width

Table 5 Analysis of MRR data

Source	DF	SS	MS	F	P
A: current	2	64.206	32.103	11.46	0.080
B: T-on	2	28.792	14.396	5.14	0.163
C: T-off	2	46.539	23.269	8.31	0.107
Error	2	5.603	2.801		

Total	8	145.140			

R-Sq = 96.14 %

DF: Degree of Freedom, SS: Sum of Square, MS: Mean Square

Table 6 Analysis of Surface Roughness data

Source	DF	SS	MS	F	P
A: current	2	0.1586	0.0793	0.68	0.595
B: T-on	2	0.5761	0.2860	2.47	0.288
C: T-off	2	0.0385	0.0192	0.16	0.858
Error	2	0.2333	0.1166		
Total	8	1.0064			

R-Sq = 94.66 %

Table 7 Analysis of Kerfwidth data

Source	DF	SS	MS	F	P
A: current	2	0.0004896	0.0002448	24.21	0.040
B: T-on	2	0.0005242	0.0002621	25.92	0.037
C: T-off	2	0.0001242	0.0000621	6.14	0.140
Error	2	0.0000202	0.0000101		
Total	8	0.0011582			

R-Sq = 98.25 %

Analysis of the Orthogonal array leads to the conclusion that factors at level A3,B3 and C2 gives maximum MRR, factors at level A2,B1 and C2 gives minimum SR and factors at level A1,B1 and C1 gives minimum Kerf width.

IV. OPIMIZATION USING GREY-TAGUCHI METHOD

Through the grey relational analysis, a grey relational grade is obtained to evaluate the multiple performance characteristics. As a result, optimization of the complicated multiple performance characteristics can be converted into the optimization of a single grey relational grade.

Table 8. S/N ratio values and normalized S/N ratio values

Exp. No.	Control Factors			S/N ratios			Normalized S/N ratios		
	Current	T-on	T-off	MRR	SR	Kerf	MRR	SR	Kerf
1	3	16	4	11.5406	-7.9934	12.5786	0.1437	0.5762	-0.4596
2	3	32	8	11.5383	-8.3660	12.3596	0.1436	0.5137	-0.6597
3	3	48	12	8.74549	-8.2323	12.3596	-0.0298	0.5361	-0.6597
4	5	16	8	14.7946	-6.8878	12.5417	0.3457	0.7617	-0.4933
5	5	32	12	12.6895	-9.2778	12.1813	0.2150	0.3607	-0.8226
6	5	48	4	19.4060	-9.3076	11.7676	0.6320	0.3557	-1.2006
7	7	16	12	10.3965	-7.5315	12.3596	0.0727	0.6537	-0.6597
8	7	32	4	22.4049	-9.2479	11.6339	0.8182	0.3657	-1.3227
9	7	48	8	22.5323	-10.604	11.4373	0.8261	0.1382	-1.5024

Table 9 Grey Relational Co-efficient and Grey relational Grade

Exp. No.	Control Factors			Grey Relational Co-efficient			Grey Grade
	Current	T-on	T-off	MRR	SR	Kerf	
1	3	16	4	0.4210	0.6295	0.2880	0.4462
2	3	32	8	0.4210	0.5874	0.2607	0.4230
3	3	48	12	0.3717	0.6018	0.2607	0.4114
4	5	16	8	0.4981	0.7991	0.2830	0.5267
5	5	32	12	0.4454	0.5049	0.2420	0.3974
6	5	48	4	0.6724	0.5026	0.2075	0.4608

7	7	16	12	0.3993	0.6907	0.2607	0.4503
8	7	32	4	0.8705	0.5073	0.1984	0.5254
9	7	48	8	0.8815	0.4193	0.1863	0.4957

Table 10 The main effect of factors on Grey Relational Grade

Control Factors	Level 1	Level 2	Level 3
A: current	0.4269	0.4616	0.4904*
B: T-on	0.4243	0.4486	0.4559*
C: T-off	0.4774*	0.4718	0.4196

* Optimum Level

V .CONFIRMATION EXPERIMENT

The confirmation test for optimal parameters with its selected levels was conducted to evaluate the response characteristics for WEDM of P20 steel. The comparison is shown in table 11.

Table 11 Optimization results

	Orthogonal Array	Grey Theory Design	% Improvement
Level	A3 B3 C2	A3 B3 C1	
MRR	13.385	14.427	7.78 %
SR	3.39	3.18	6.19 %
Kerf width	0.268	0.245	8.58 %

VI. CONCLUSION

This study experimentally investigated the relationship of response parameters like Material Removal Rate, surface finish and kerf width with current and pulse on and pulse off time on WEDM of P20 steel. Some of the findings are as below.

1.With increase in current, response parameters Material removal rate, surface roughness and kerf width increases.
2.With increase in pulse time on, material removal rate, kerf width and surface roughness increases.
3.With increase in pulse –off time MRR, surface roughness and kerf width decreases.
4The optimal process parameters based on Grey Relational Analysis for the Reusable wire EDM of P20 tool steel are 7 amp current , 48 µs T-on time and 4 µs T-off time. By using Grey-Taguchi method, the MRR, Surface roughness and Kerf width improves by 7.78 %, 6.19 % and 8.58 % respectively.

ACKNOWLEDGEMENT

Authors would like to acknowledge L.D. College of Engineering, Ahmedabad for allowing permission to carry out experiments and to utilize their valuable resources.

REFERENCES

[1] Kalpakjian S., Steven R., Schmid,“Manufacturing Process for Engineering Materials”, Fourth Edition, Pearson Publishers, 2010.

[2] Kumar A.,“Modelling Of Micro Wire Electro Discharge Machining (WEDM) In Aerospace Material”, NIT Rourkela, 2012.

[3] Ch. V. S. ParameswaraRao, M. M. M. Sarcar,,Experimental Investigation and Development Of Mathematical Correlations Of Cutting Parameters, Journal of Mechanical Engineering, Vol. ME 40, No. 1, June 2009 Transaction of the Mech. Eng. Div., The Institution of Engineers

[4] S.S. Mahapatra, A. Patnaik, Optimization of WEDM process parameters using Taguchi method, The International Journal of Advanced Manufacturing Technology 34/9-10 (2007) 911-925.

[5] H. Singh, R. Garg, Effects of process parameters on material removal rate in WEDM, Journal of Achievements in Materials and Manufacturing Engineering, VOLUME 32, ISSUE 1, January 2009.

[6] S.B.Prajapati and N.S. Patel (2013), Effect of process parameters on performance measure of wire edm for AISI A2 tool steel, International journal of Computational Engineering Reseacrh, vol, 03 issue, 4.

[7] An approach to optimization of process parameters in wire EDM discharge machining for EN24 alloy steel. Sandeep malik , Dr. Vineet Singla IJREAS Volume 3, Issue 5 (May 2013) ISSN: 2249-3905

[8] Niladri Mandal, P Saha, K Ramesh Kumar, DR Yadav, Study on Machining Parameter Optimization for WEDM of Nimonic C263 - A Taguchi Approach, Proc. of the 3rd International Conference on Advances in Mechanical Engineering, January 4-6, 2010, S.V.N.I.T, Surat.

[9] Murali M. Sundaram, Ganesh B. Pavalarajan, and Kamlakar P. Rajurkar, A Study on Process Parameters of Ultrasonic Assisted Micro EDM Based on Taguchi Method, Journal of Materials Engineering and Performance, 210—Volume 17(2) April 2008.

[10] R.A. Mahdavinejad, Optimisation of electro discharge machining parameters, Journal of Achievements in Materials and Manufacturing Engineering, volume 27, Issue 2, April 2008.

[11] Y.M.Puri and N.V.Deshpande, simultaneous optimization of multiple quality characteristics of WEDM based on fuzzy logic and Taguchi technique, Proceedings of the Fifth Asia Pacific Industrial Engineering and Management Systems Conference 2004,14.18.1

[12] Muthu Kumar V, Suresh Babu A, Venkatasamy R, Raajenthiren M, Optimization of the WEDM Parameters on Machining Incoloy800 Super alloy with Multiple Quality Characteristics, International Journal of Engineering Science and Technology , Vol. 2(6), 2010, 1538-1547