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Investigations of Effect of Process Parameters on Material Removal Rate in Wire-cut Electrical Discharge Machining of Steel Grade EN 9

Kashid D.V.[1], S.G. Bhatwadekar[2],S.B. Sangale[3], P.R. Kubade[4]

[1]PG Student, Department of Prod. Engg., KIT's College of Engineering, Kolhapur, Maharashtra, India

[2]Associate Professor, Department of Prod. Engg., KIT's College of Engineering, Kolhapur, Maharashtra, India

[3,4]Assistant Professor, Department of Prod. Engg., KIT's College of Engineering, Kolhapur, Maharashtra, India

*Corresponding Author. E-mail: kashid.deep@yahoo.in

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 steel grade EN 9 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 L_9 orthogonal array. Signal to Noise ratios of the Material removal rate 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, Wire feed, Material removal rate.*

1. Introduction

Wire electrical discharge machining or WEDM is process not only used for machining ferrous and non-ferrous alloy but also materials of any hardness which are electrically conductive. Due to continued development of mechanical products, the demand for alloy materials (used in forestry tools and equipments, mining tools, structural applications etc.) with high hardness, toughness and impact resistance is increased. Such materials are difficult to machine by conventional machining method.

WEDM provides the best alternative for machining conductive, high strength material for generating intricate shapes and profile. The WEDM machine is specialized in cutting complex contours or fragile geometry that would be difficult to produced using conventional cutting method. The broad capabilities of WEDM allow it to cater to the needs of the aerospace and automotive industries and nearly all areas of conductive material machining.

A. Manna devised an experimental investigation to determine the parameters setting during the machining of aluminium-reinforced silicon carbide metal matrix composite (Al/SiC-MMC). According to the Taguchi quality design Concept, a L_{18} orthogonal array was used to determine the S/N ratio, ANOVA and the F-test values were used to indicate the significant machining parameters which affected the machining performance. With help of experimental results, ANOVA and F-test values, the significant factors were determined for each machining performance criteria such as material removal rate, surface finish, gap current and spark gap.

H. Singh investigated on the effect and optimization of machining parameter on material removal rate in WEDM operations. The experimental studies were conducted under varying pulse-on time, pulse-off time, gap voltage, peak current, wire feed and wire tension. The effect of process parameters were studied on MRR for H-11 using one factor at a time approach.

Pujari Srinivas Rao carried out work on parametric optimization method for WEDM of Aluminium BIS-24345 alloy using Taguchi's robust design. Experiments were conducted under different conditions of pulse-on time, pulse-off time, peak current, flushing pressure of dielectric fluid, wire feed rate, wire tension, spark gap voltage and servo feed setting. Material removal rate was considered as performance characteristics. This method used was for obtaining the optimal combination of parameters. Mathematical and artificial neural network models were developed relating the machining performance and process parameters.

S.S. Mahapatra (2007) studied the relationships between various control factors and responses like material removal rate, surface finish and kerf. This finally resulted in a valid mathematical model. Genetic algorithm was employed to optimize the WEDM process with multiple objectives. The study demonstrates that the WEDM process parameter was adjusted to achieve better material removal rate, surface finish and cutting width simultaneously.

2. TAGUCHI METHOD

Since 1960, Taguchi method has been used for improving the quality of Japanese product with great success. In the Taguchi method, experimental values are transformed into S/N ratio. Signal represents the desirable value (i.e. the mean for the output characteristics), and noise represents the undesirable value (i.e. the square deviation for the output characteristics). It is denoted by 'η' with a unit of db. In these the characteristics that higher observed value represents better machining performance is known as "higher the better" and the characteristics that lower value represent better machining performance is called "lower the better". Hence, for MRR "higher the better" is selected for obtaining optimum machining performance characteristics.

S/N ratio for MRR,

$\eta = -10 \, Log_{10} \, (MSD)$

MSD= Mean squared deviation from the target value of the quality characteristics

$$= \left(\frac{1}{y_1^2} + \frac{1}{y_2^2} + \frac{1}{y_3^2} + - - + \frac{1}{y_n^2} \right) \div N$$

Where, y_i is result observation

N is number of repetitions

The aim of this study was to produce maximum material removal rate (MRR) in WEDM machining operation. Higher the better characteristic is used for material removal rate.

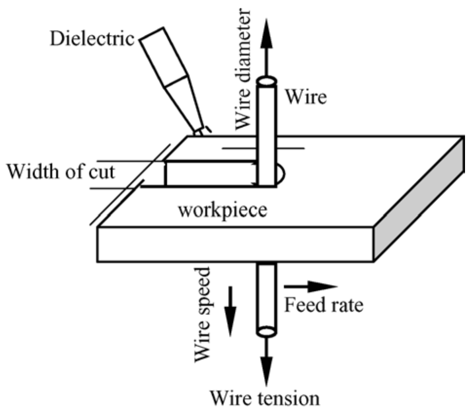

Fig.1 *Wire-EDM Process*

3. EXPERIMENTAL DESIGN

3.1. Experimental Set-Up and wire electrode

Experiments were performed on a (Model: 'Sprintcut Elpuls 40 A DLX' CNC wire electrical discharge machine. A negatively charged brass wire with diameter of 0.25 mm was used as the tool. The chemical composition of the material given in percentage of mass is as follows, C=0.5-0.6, Mn=0.5-0.8, Si=0.05-0.35, S=0.040 Max, P=0.040 Max. The size of the work-piece considered for experimentation on the WEDM is 100 mm x 20 mm x 3.8 mm. For each experiment the combinations of the 3 input parameters viz. Pulse-on time in the range of 114-122 (μs), pulse-off time in the range of 46-54 (μs), wire feed in the range of 3-5 (mm/s), all having 3 levels (Table 1). These were chosen from literature and preliminary investigations.

Table 1. *WEDM Parameters and Levels*

Sr.No	Parameters	symbol	Level 1	Level 2	Level 3
1	Pulse on time (μs)	T_{On}	114	118	122
2	Pulse off time (μs)	T_{Off}	46	50	54
3	Wire feed (mm/s)	W_f	3	4	5

3.2. Data collection

The cutting speed (V_C) is directly displayed on the computer monitor of the machine tool, for various settings of experimental machining operation. From this data Material removal rate is estimated as follows,

$MRR = V_C * b * h \ mm^3/min$

Where:

V_C = Cutting speed in mm/min

b = Width of cut in mm (measured after the cut)

h = Height of the work-piece in mm as per drawing

4. Determination of Optimal Cutting Parameters

For the experimental trials, an orthogonal array is used. It consists of a set of experiments where the settings of several products or process parameters to be studied are changed from one experiment to another. Results obtained from the experimentation are studied with the help of S/N and ANOVA analysis. By using these results, optimal cutting parameters for maximum material removal rate are obtained. The analysis is made using the software MINITAB 13.

4.1. Analysis of the S/N ratio

Higher the better performance characteristic is selected to obtain maximum material removal rate. Parametric combinations of factors are as shown in Table 2.

Table 2. *L_9 orthogonal array*

Ex. No	T_{On}	T_{Off}	W_f
1	114	46	3
2	114	50	4
3	114	54	5
4	118	46	4
5	118	50	5
6	118	54	3
7	122	46	5
8	122	50	3
9	122	54	4

There are two repetitions for each experiment. Hence with the help of two repetitions, average of material removal rate can found out. The experimental results for material removal rate and the corresponding S/N ratio using equation (1) are shown in Table 3.

Table 3. *Calculations for S/N ratio*

Ex. No	MRR 1	MRR 2	Avg. MRR	S/N ratio
1	6.276	6.272	6.274	15.951
2	5.2	4.8	5	13.968
3	4.349	4.347	4.347	12.773
4	6.817	6.811	6.814	16.675
5	6.049	6.041	6.045	15.638
6	5.365	5.361	5.363	14.596
7	6.816	6.812	6.814	16.675
8	7.109	7.113	7.111	17.055
9	6.159	6.157	6.158	15.800

Figure 2 show the S/N ratio graph for material removal rate. The graph shows that material removal rate increases with the increase in pulse-on time. If pulse-off time increases, then material removal rate decrease. Wire feed rate have less significant effect on material removal rate as compared to pulse-on time and pulse-off time but as wire feed increases, the material removal rate decreases.

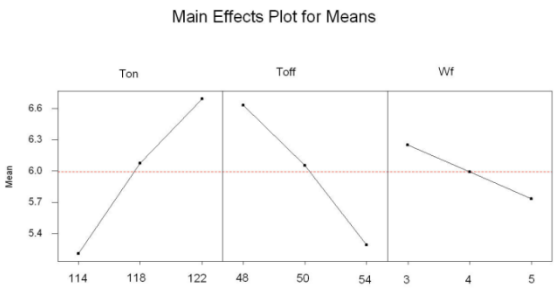

Fig.2 *Main Effect Plots for means for MRR*

4.2. Analysis of Variance (ANOVA)

The values obtained from the experiments were analysed using analysis of variance technique. Analysis of variance is performed to control the process variation and it used to determine significant parameters which affect the performance characteristics. This decision can be made based on the results obtained. With the help of ANOVA, the parameters can be categorized into significant and insignificant parameters.

Table 4. *Analysis of variance for MRR, using Adjusted SS for Test*

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ton	2	3.3487	3.3487	1.6743	10.28	0.089
Toff	2	2.7285	2.7285	1.3643	8.38	0.107
Wf	2	0.3963	0.3963	0.1981	1.22	0.451
Error	2	0.3257	0.3257	0.1628		
Total	8	6.7991				

With help of response table for S/N ratio for MRR, most significant parameter and rank of parameters can easily identified.

Table 5. *Response table for S/N ratio for MRR*

Level	T_{ON}	T_{OFF}	W_F
1	14.1214	16.4290	15.8592
2	15.6280	15.5486	15.4787
3	16.4985	14.3802	15.0199
Delta	2.2671	2.0487	0.8393
Rank	1	2	3

4.3. Results and analysis

From above results, we were concluding that material removal rate was highly influenced by pulse-on time and pulse-off time. The higher discharge energy, the more powerful explosion and the deeper crater created on the machined area. Pulse on-time (T_{ON}) with a contribution of 51.7103% has greatest effect on the machining output characteristics. Parameter pulse-off time (T_{OFF}) is the next most significant influence 42.153% on the material removal rate. It reveals that wire feed rate has less effect on the material removal rate as compare to pulse on-time and pulse-off time. Hence if requirement of material removal rate is high, then pulse on-time and pulse-off time must high. Optimum material removal rate can be obtained by choosing those parameters suitably.

5. CONCLUSION

The effect of pulse-on time, pulse-off time and wire feed are investigated in machining of of steel grade EN 9 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.

Pulse-on time (T_{ON}) and pulse-off time (T_{OFF}), are the most significant influencing machining parameters respectively, for the material removal rate.

For maximum MRR, the recommended parametric combination is A3-B1-C1.

The parameter wire feed (W_F) have very less effect on the material removal rate.

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.

REFERENCES

[1] Z.N Guo, X. Wang, Z.G. Huang and T.M Yue, "Experimental investigation into shaping particle-reinforced material by WEDM-HS", Journal of Materials Processing Technology 129, pp. 56-59, 2002.

[2] Nihat Tosun and Can Cogun, "An investigation on wire wear in WEDM", Journal of Materials Processing Technology 134, pp. 273-278, 2003.

[3] Y.M Puri and N.V Deshpande, "Simultaneous Optimization of multiple quality characterstics of WEDM based on fuzzy logic and Taguchi technique", Proceedings of the Fifth Asia Pacific Industrial Engineering and Management System Conference, pp. 14.18.1-14.18.12.2004.

[4] Biing Hwa Yan, Hsien Chung Tsai, Fuang Yuan Huang and Long Chorng Lee, "Examination of wire electrical discharge machining of Al2O3p/6061Al composites", International Journal of Machine Tools & Manufacture 45, pp. 251–259,2005.

[5] M.S. Hewidy, T.A. El-Taweel and M.F. El-Safty, "Modelling the machining parameters of wire electrical discharge machining of Inconel 601 using RSM", Journal of Materials Processing Technology 169, pp. 328–336,2005.

[6] A. Manna and B. Bhattacharyya, "Taguchi and Gauss elimination method: A dual response approach for parametric optimization of CNC wire cut EDM of PRAlSiCMMC", International Journal of Advance Manufacturing Technology, pp. 67–75,2006.

[7] K. Kanlayasiri and S.Boonmung, "An investigation on effects of wire-EDM machining parameters on surface roughness of newly developed DC53 dies steel", Journal of Materials Processing Technology 187–188, pp. 26–29, 2007.

[8] S.S.Mahapatra and Amar Patnaik, ''Optimization of wire electrical discharge machining (WEDM) process parameters using

Taguchi method'', International Journal of Advance Manufacturing Technology, pp. 911-925, 2007.

[9] K. Kanlayasiri and S.Boonmung, "Effect of wire-EDM maching variables on surface roughness of newely developed DC 53 die steel: Design of experiments and regression model", Journal of Materials Processing Technology 192–193, pp. 459–464, 2007.

[10] M.J. Haddad and A. Fadaei Tehrani, " Material removal rate (MRR) study in the cylindrical wire electrical discharge turning (CWEDT) process", Journal of materials processing technology I99, pp. 369-378 ,2008.

[11] H. Singh and R. Garg, "Effects of process parameters on material removal rate in WEDM", Journal of Achievements in Materials and Manufacturing Engineering VOLUME 32 ISSUE 1, pp. 70-74. Jan. 2009

[12] Pujari Srinivasa Rao, Dr. Koona Ramji and Prof. Beela Satynarayana, "Prediction of Material removal rate for Aluminum BIS-24345 Alloy in wire-cut EDM", International Journal of Engineering Science and Technology Vol. 2 (12), pp. 7729-7739, 2010.

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

[14] Pujari Srinivasa Rao, Koona Ramji and Beela Satyanarayana, "Effect of WEDM conditions on surface roughness: A Parametric Optimization using Taguchi method", International Journal of Advanced Engineering Sciences and Technologies Vol No.6, Issue No. 1, pp. 041-048, 2011.

[15] Pragya Shandilya, P.K. Jain and N.K. Jain, "Parametric optimization during wire electrical discharge machining using response surface methodology", Procedia Engineering 38, pp. 2371-2377, 2012.

[16] V.K. Saini, Zahid A. Khan and Arshad Noor Siddique, "Optimization of wire electric discharge machining of composite material (AL6061/SICP) using Taguchi Method", International Journal of Mechanical and Production Engineering (IJMPE) No.:2315-4489, Vol-2, Iss-1, pp. 61-64,2013.

[17] S.B. Prajapati and N.S. Patel, "Effect of process parameters on performance Measures of Wire EDM for AISI A2 Tool Steel", International Journal of Computational Engineering Research Vol.03, Issue-4, pp. 274-278, 2013.