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Investigation of Surface Roughness and MRR on Stainless Steel Machined by Wire EDM

M. Shunmuga Priyan , W. Willbert Swin, V. Anand, P. Kelvin, V. Sai Siva
Department of Mechanical Engineering,
Loyola Institute of Technology & Science,
Thovalai, Tamil Nadu - 629302

***Abstract* - Wire electrical discharge machining (WEDM) is an important technology, which demands high-speed cutting and high-precision machining to realize productivity and improved accuracy for automotive, manufacturing of press stamping dies, prototype parts etc. In this present work, investigations of cutting performance with pulse on time, pulse off time, servo voltage, wire feed, current and cutting speed were experimentally investigated in wire electric discharge machining (WEDM) process. Brass wire with 0.25mm diameter and SS 304 with 575 × 835 × 200 mm were used as tool and work materials in the experiments. The cutting performance outputs considered in this study are material removal rate (MRR) and surface roughness. Experimentation has been completed by using Taguchi's L16 orthogonal array under different conditions of parameters. The aim of the present investigation is to develop the selection of an optimal combination of WEDM parameters for proper machining of SS 304 to achieve better surface roughness and Materials Removal Rate (MRR).**

1. INTRODUCTION

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the workpiece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the workpiece. This removes (erodes) very tiny pieces of metal from the workpiece at a controlled rate. Puertas and Luis (2005), investigated the optimization of machining parameters used for EDM of Boron carbide of conductive ceramic materials. It is these conditions were determined the important characteristics as surface roughness, electrode wear, and MRR. Wang and Lin (2000), The Taguchi method and L18 orthogonal array to obtain the polarity, peak current, pulse duration, duty factor, rotary electrode rotational speed, and gap load voltage in order to explore the material removal rate, electrode wear rate, and surface roughness. Miller et.al (2005), determined the WEDM is a complex machining process controlled by a large number of process parameters such as the pulse duration, discharge frequency and discharge current. Tosun et al (2003) modelled the variation of response variables with the machining parameters using regression analysis method and then applied simulated annealing searching for determination of the machining parameters that can simultaneously optimise all the performance measures, e.g. kerf and MRR. Several attempts were made to perform a parametric study from time to time (Han et al 2007 , Jin et al 2008, Kanlayasiri et al 2007, Liao et al 2004). Mahapatra and Patnaik (2007) established the relationship between various processes. (Han et al 2007, Jin et al 2008, Kanlayasiri et al 2007, Liao et al 2004). Mahapatra and Patnaik (2007) established the relationship between various process parameters and responses using non-linear regression analysis and then employed genetic algotithm to optimize the WEDM process.Chiang and Chang (2006) optimised the surface roughness and Material Removal Rate of a WEDM process for Al2O3 particle reinforced material based on Grey Relational Analysis method. chiang and chang (2006) used Grey Relational analysis to determine optimal WEDM parameters for machining Al_2O_3 particle reinforced material with multiple performance characteristics. Different materials even when they are machined under the same machining conditions exhibit different machining characteristics. It is difficult to control and predict the machining characteristics in WEDM. There are very few studies on this on this subject so far. Almost the studies concerned with material, deal with the effect of electrode materials on machinability in WEDM (prohaszka et al 1997). Levy and magi (1990) have compared the influence of material properties of different steels on machining characteristics, but only qualitatively. It is extremely difficult to conclude and pinpoint definite physical quantity that can fully reflect the material properties for WEDM, and use it to predict machining characteristics (Dibitonto et al 1989, Dijck 1972, Eubank et al 1993) . This paper was reported to the shortest machining time whilst at the different time satisfying the requirements of MRR and surface roughness by using Taguchi's Method.

2. EXPERIMENTAL DETAILS

Process Parameters Selection

The experiments were carried out on a Wire Electro Discharge Machine (WEDM) ELECTRONICA "ECOCUT" of M/S Electronic Machine Tools Ltd. Installed at Precision Engineering Lab of Manufacturing Engineering Department , College of Engineering, ANNA UNIVERSITY"Guindy,Chennai-25, Tamil Nadu, India. The discussions related to the measurement of WEDM Experimental Parameters, material Removal Rate (MRR), Surface Roughness are presented in the following.

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Process parameters of Wire-EDM process in Table: 1

SI. No	Parameters	Range
1	Wire Material	Diffused Brass Wire
2	Wire Size (mm)	Ø 0.25
3	Wire tension (gm)	1600
4	Dielectric	Deionised water
5	Table feed rate (mm/min)	80
6	Work Piece	SS 304

Material Removal Rate (Mrr)

For WEDM, MRR is o a desired characteristic and it should be high as possible to give less machine cycle time leading to increased productivity in the present study MRR is calculated as MRR = K × t ×Vc × p Where, K = kerf width, Vc= cutting speed, ρ = density of material, t = thickness of material.

Selection of the Work Piece

Typical compositional ranges for grade 304 stainless steels are given in table: 2

Grade Wt.%	C	Mn	Si	P	S	Cr	Mo	Ni	N
304	0.08	2	0.75	0.04	0.03	20	-	10.	0.1

Typical mechanical properties for grade 304 stainless steels are given in table: 3

Grade	Tensile Strength(Mpa) min	Yield Strength(Mpa) min	Elongation(% in 50mm)min	Hardness(BHN)
304	515	205	40	201

Taguchi design experiments in MINITAB

MINITAB provides both static and dynamic response experiments in a static response experiment; the quality characteristic of interest has a fixed level. The goal of robust experimentation is to find an optimal combination of control factor settings that achieve robustness against (insensitivity to) noise factors. MINITAB calculates response tables and generates. A Taguchi design or an orthogonal array the method is designing the experimental procedure using different types of design like, two, three, four, five, and mixed level. In the study, a three factor mixed level setup is chosen with a total of eighteen numbers of experiments to be conducted and hence the OA L16 was chosen. This design would enable the two factor interactions to be evaluated. As a few more factors are to be added for further study with the same type of material, it was decided to utilize the L16 setup, which in turn would reduce the number of experiments at the later stage. In addition, the comparison of the results would be simpler. This project makes use of Taguchi's method for designing the experiments. Hence L16 mixed orthogonal array was selected for the present investigation. Parameters and their levels selected for final experimentation has been depicted in Table. Experimental analysis using pooled ANOVA predicts the significant process parameters and to establish the optimal parameter set of combinations for Wire-EDM of SS 304.

Taguchi Design

It is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. When used properly, 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."

Results And Discussion

In this chapter are related about influences of MRR, TWR, Surface Roughness finding the result which factors discharge current, pulse duration, diameter of brass tool, is most important with help of Taguchi method. The response table for MRR Surface Roughness is shown in Table 4 along with the input factors. In this investigation, the effects of WEDM essentials parameters such as peak current (A), Pulse on time (Ton), Pulse off time (Toff) and gap voltage (V) were varied to determine their effects on material removal rate (MRR) and surface roughness (SR). In addition, the experimental data were transferred to grey relational grade and were assessed by analysis of variance (ANOVA) to determine the significant machining parameters and to obtain the optimal combination levels of machining parameters for multiple performance characteristics. Therefore, the optimal machining parameters of the WEDM were established to achieve a high MRR along with a good surface roughness for the difficult to machine materials.

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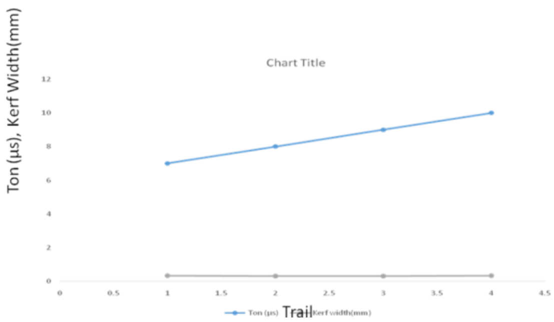
RESPONSE TABLE 4

Sl.No	T(on) (μs)	T(off) (μs)	Wire feed (m/mim)	Voltage (V)	Current (A)	M/c speed (mm/min)	Time (min)	Kerf width (mm)	Ra (μm)	MRR (mm^3/min)
1	10	1	1	45	2.9	2.1	8.19.61	0.308	2.52	20.4
2	10	2	2	50	2.5	1.9	9.33.32	0.294	2.01	17.6
3	10	3	3	55	2.1	1.5	11.07.38	0.319	1.82	15.2
4	10	4	4	60	1.9	1.2	14.10.30	0.339	2.5	12.8
5	9	1	2	55	2.5	1.7	9.46.63	0.297	1.75	16
6	9	2	1	60	2.1	1.5	12.00.29	0.29	2.72	13.7
7	9	3	4	45	2.5	1.9	9.28.04	0.308	2.23	18.4
8	9	4	3	50	2.1	1.7	10.48.86	0.299	1.88	16
9	8	1	3	60	2	1.5	11.42.96	0.307	1.95	14.5
10	8	2	4	55	2.1	1.6	10.46.04	0.305	3.11	15.4
11	8	3	1	60	1.9	1.2	12.34.67	0.311	1.84	11.7
12	8	4	2	45	2.1	1.7	9.44.80	0.302	1.88	16.2
13	7	1	4	50	2.1	1.7	9.28.38	0.307	1.67	17
14	7	2	4	45	2.2	1.7	9.14.87	0.336	1.64	18
15	7	3	2	60	1.9	1.2	13.21.78	0.291	1.71	11
16	7	4	1	55	1.9	1.6	11.50.56	0.307	1.8	15.2

Experimental Design

In this work, grey relational analysis was adopted to evaluate the multiple performance characteristics of MRR and Surface Roughness for six different materials. The grey relational grade was treated as the overall evaluation of experimental data for the performance characteristics using L16 orthogonal array. From this above array table, we have chosen

the orthogonal array of L-16 since our No of factors is 4 are pulse on time, pulse off time, peak current, wire material, work piece material. Minitab 15 software was used for graphical analysis of the obtained data. It is evident from the results that, MRR increases upon increasing Pulse on Time, Pulse off Time, Pulse Peak Current. We can achieve the nominal output response (ie Max MRR, Min SR). The relevant input parameters, we can achieve maximum Metal Removal Rate (MRR).Surface Roughness decreases upon increasing Pulse on Time and increasing upon increasing Pulse off time and Peak Current. Based on the input parameters, we can achieve minimal Surface Roughness (SR).EWR reduces upon increasing Pulse off Time and Peak Current. By choosing the input parameters are optimizing, we can achieve minimal Electrode Wear Rate (EWR).



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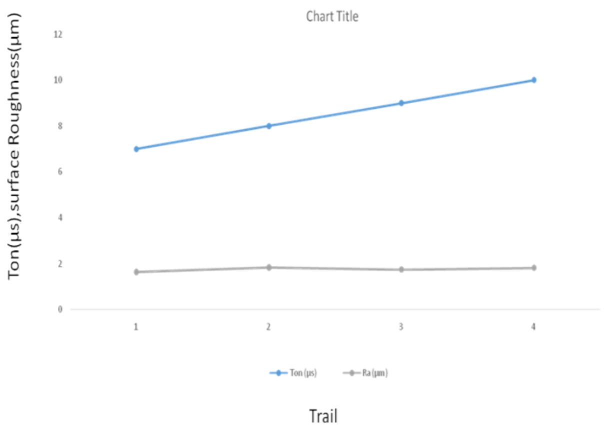
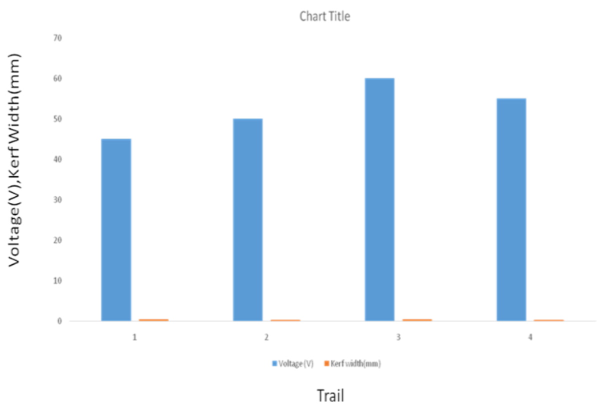


Figure 1: Graph plot between surface roughness and Kerf width

Surface roughness increases with increase in current density. As the current increases surface of the final product becomes more and more rough. With the current increases from 1.9 ampere to 2.9 ampere surface roughness nominal value increases from 1.75 to 2.5 µm. Also, current and surface roughness relationship can be graphed as shown in figure 1. In Wire EDM specifically is based on application requirements are in Maximum MRR and Minimum Surface Roughness was achieved in previous author. In this condition from the graph shows better response at room condition. From the condition surface was revealed better surface roughness condition at this maximum input parameters.



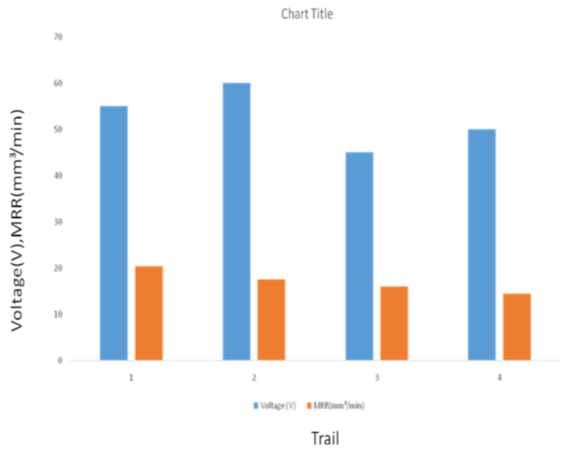


Figure 2: Graph plot Voltage Vs MRR and Kerwidth

Material removal rate increases with increase in current density. As current density increases material removal rate also increases. From figure as current density increases from 18 ampere to 22 ampere material removal rate increases from 11 to 20.3 mm3 / minute. Based on the current densities and increase of current with the temperature between the electrodes and work-piece due to which more vaporization of work-piece takes place. The graph between material removal rate and current is shown in Figure 2. The grey relational grade represents the level of correlation between the reference sequence and the comparability sequence, the greater value of the grey relational grade means that the comparability sequence has a stronger correlation to the reference sequence. Based on grey relational grade value were given by average response in table. In this table, higher grey relational grade from each level of factor indicates the optimum level. The Pulse on time (10 µs), Pulse off time (4 µs) and Servo voltage (60 volts) respectively.

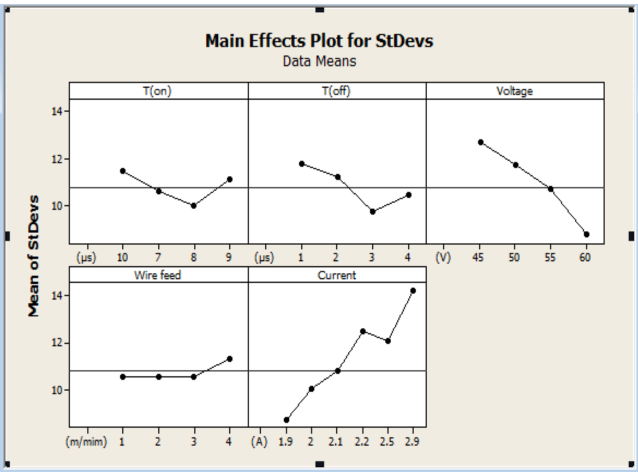


Figure 3: Effect of plot for standard deviations

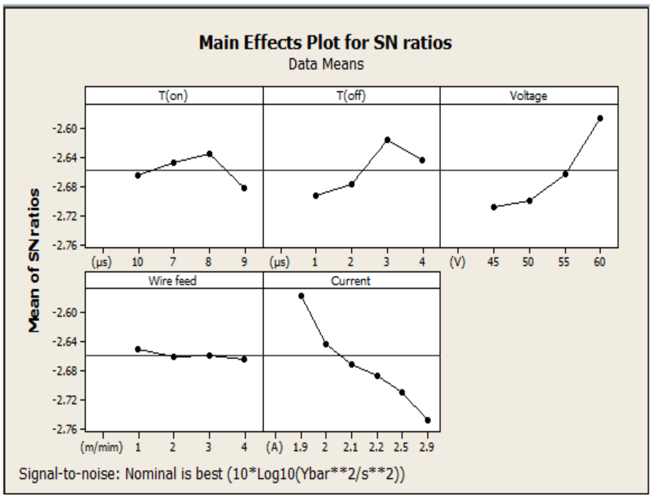


Figure 4: Effect of plot for S/N ratio

The above graph (Figure 3) between Pulse on Time, Pulse off Time with determine the MRR and Surface roughness value increased and decrease based on optimization parameters. In this parameters were determine the characterization of materials (SS 304) and high material removal rate also identified.

Figure show that the MRR increases with the increase in pulse on time, peak current and decreases with increase in pulse off time and servo voltage. The effects of servo feed on MRR are not very significant. Analysis of Variance (ANOVA) table shows that the significance of the process variables towards surface roughness. The response table 4 shows the average of response characteristic for each level of each factor. The Table includes ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on delta values; rank 1 to the highest delta value, rank 2 to the second highest, and so on. The ranks indicate the relative importance of each factor to the response. The ranks and the delta values for various parameters show that pulse on time has the greatest effect on surface roughness and is followed by servo voltage, pulse off time, peak current , and servo feed rate in that order. As surface roughness is the "lower the better" type quality characteristic, from Figure it can be seen that the first level of pulse on time(A1), first level of pulse off time(B1), second level of peak current (C2), first level of servo voltage(D1), first level of servo feed (E1) result in minimum value of surface roughness.

From Figure 4 , it can be seen that for a particular value of input parameter the corresponding range of occurrence of kerf width can be determined and vice versa. The experimental result confirms the optimization of the machining parameters using Taguchi method for enhancing the machining performance. However, the error in MRR and surface roughness can be further expected to reduce if the number of measurements is increased. The figure 5 shows express with the analysis of variance between MRR and Kerf width. The effects of pulse on time, pulse off time, peak current, servo voltage and servo feed on MRR and surface roughness were experimentally investigated in machining of Stainless Steel 304 using CNC Wire-cut EDM process

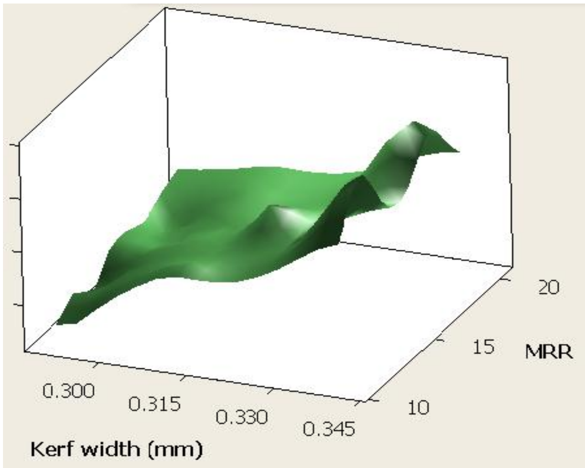


Figure 5: 3D contour plot analysis Kerf width Vs MRR

CONCLUSION

In the presented work, experiments are carried out for material removal rate, surface roughness and Kerf width with variables as pulse on time, pulse off time and servo voltage. There are 16 experimental readings taken for all variables to conduct the parametric study. Finally it can be concluded that: Grey relational analysis is done to find out optimal parameter levels. After grey relational analysis, it is found that pulse on time at level 3 (10µs), pulse off time at level 3 (4 µs), servo voltage at level 2 (60 volts) are the best process parameter for the MRR, Kerf width and Surface roughness. Process parameters do not have some little effect for every response. Increase of Pulse on time generates more spark energy as the length of time that electricity supply increases. MRR, Kerf width and Surface Roughness all response increasing with pulse on time. Pulse on time found most significant parameter in all response. Surface roughness also increases with increase of pulse on time because the increases of pulse on time produce crater with broader and deeper characteristic. Pulse off time has opposite effect to pulse on time. MRR decrease with increase of pulse off time, while surface roughness reduces. During off time removed material

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flushed away. More the off time better the flushing. Servo voltage has little effect on SR and KERF width but it has more effect over MRR. Surface roughness reduces with increase of servo voltage.

REFERENCES

[1] Pandit,S.M. and Rajurkar, K.P., "A Stochastic approach to thermal modelling applied to electro-discharge machining" Transactions of the ASME, Journal of Heat Transfer,Vol.105,pp.107-116,2007.

[2] Mahapatra, S. and Patnaik, A. "Optimization of wire electrical discharge machining (WEDM) process parameter using Taguchi method " International Journal of advanced Manufacturing Technology,Voi.34,pp.911-925,2007.

[3] Han,F.,Jiang,J.and Dingwen,Yu. "influence of machining parameters on surface roughness in finish cut of WEDM", international journal of Advanced manufacturing technology,Vol.34,pp.538-546,2007.

[4] Miller, S.F., Shih,A .J and QU,J. "Investigation of the spark cycle on Material removal rate in wire electrical discharge machining of advanced materials", International Journal of Machine Tool& Manufacture, Vol,44,pp.391-400,2004.

[5] Lin,J.L. and Lin,C.L. "the use of grey-fuzzy logic the optimization of the manufacturing process" Journal of Materials processing Technology,Vol.160,pp.9-14,2005.

[6] Lazarenko, B.R. and Lararenko. N.I., " The physics of the electric spark method of machining of metals ",Pb of Elect.Inddustry,USSR, Moscow,1946.

[7] Konda, R.J., Rajurkar, K.P., R.R.,Guha, A.and Parson, M., " Design of experiments to study and optimize process performance"., International journal of Ouality Reliability management, Vol.16.No 1,pp.56-71,1999.

[8] Jin,Y.,Kesheng,W., Tao,Y.Minglun,F.,"Reliable multi-objective optimization of high-speed WEDM process based on Gaussian process regression", International Journal of machine Tools and manufacture,Vol.48,pp.47-60.2008.

[9] Huang,J.T.,Liao,Y.S.and Huse, W.J. "Determination of finish-cutting operation number and machining parameter setting in wire electrical discharge machining", journal of materials processing Technology Vol.87,pp.69-81,1999.

[10] Han,F.,Jiang,J.and Dingwen,Yu. "influence of machining parameters on surface roughness in finish cut of WEDM", international journal of Advanced manufacturing technology,Vol.34,pp.538-546,2007.

[11] Electronica machine Tools Ltd., Technology manual for Wire cut Edm- Elektra "Eco cut" , pp.1-2,2009.

[12] Chang, C.K and Lu, H.S., "Design optimization of cutting parameters for side milling operations with multiple performance characteristics", Int J Adv Manuf Technol, Vol.32,pp.18-26,2007.

[13] Altpeter,F. and Roberto, p R., "Relevant topics in wire electrical discharge machining control", Journal of materials processing Technology, Vol.149,pp.147-151,2004.

[14] Hirotake Kokubo, Hideki Takezawe,Ken'ichiro Horio, Naotake Mohri and Tsugio Yamazaki, "A Study on the material removal mechanism in EDM – Single discharge experiments with low melting temperature alloy", Journal of Japan society of Electrical machining engineers Vol.42No.99,pp.5-11-2008.

[15] Ho,K.H.and Newman, S.T.,"State of the art in electrical discharge machining (EDM)", International Journal of machine Tools and Manufacture, Vol.43,pp.1287-1300,2003.

[16] Kanalayasiri, K,and Boonmung,S. "An investigation on effects of wire EDM machining parameters on surface roughness of newly developed DC53 die steel" Journal of materials processing technology,Vol.187-188,pp.26-27,2007.