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Stainless Steel 316 Wire EDM Process Parameter Optimization by Using Taguchi Method

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Abstract—

Due to revolution in the industrial automation and agile leads to development of advanced engineering materials with high precision and high quality in low-volume production. These have made the wire cut electrical discharge machining process to meet such demands. The best machining process parameters are depends on the job material and need to be optimized based on the job. So in this research, the optimal setting of the process parameters on the Wire cut electro-discharge machining for Stainless Steel 316 grade material had been obtained using Taguchi method by considering the constraints. The process parameters chosen for this research are pulse on time, pulse off time, servo voltage and wire feed rate. These chosen process parameters gain importance on different response parameters such as material removal rate (MRR) and surface roughness (Ra). The generated feasible EDM process parameters for each work-material had also validated by conducting test experiments.

Keywords— ***Optimization; Wire cut electrical discharge machining; Taguchi method;***

I. INTRODUCTION

Recently, industries are focusing towards the unconventional machining for their component manufacturing method, as it is green manufacturing process used to produce high quality product. Wire electrical discharge machining (WEDM) is an indispensable machining technique for producing complicated cut outs through difficult to machine metals without using high cost grinding or expensive formed tools [1]. So Electrical discharge machining (EDM) is one of the most extensively used unconventional machining methods which uses thermo-electric metal removal process. When the servo voltage is increased, proportionally increase in spark production and in turn temperature will be very high enough to melt the metal. Due to this high temperature, normally metal will be removed from the work piece. Material is eroded from the work piece (Anode) and wire tool electrode (Cathode) separated by deionised water such as dielectric fluid and continuously flushes away the machining debris. EDM is capable of fabricating products from a small range to a large size of components of good conductivity. However, machine process parameter setting varies for each type of metals. So, a necessity arises for setting the machining parameters like Metal removal rate, Surface Roughness, Electrode Wear Rate(EWR), etc for each of materials to obtain the required precision.

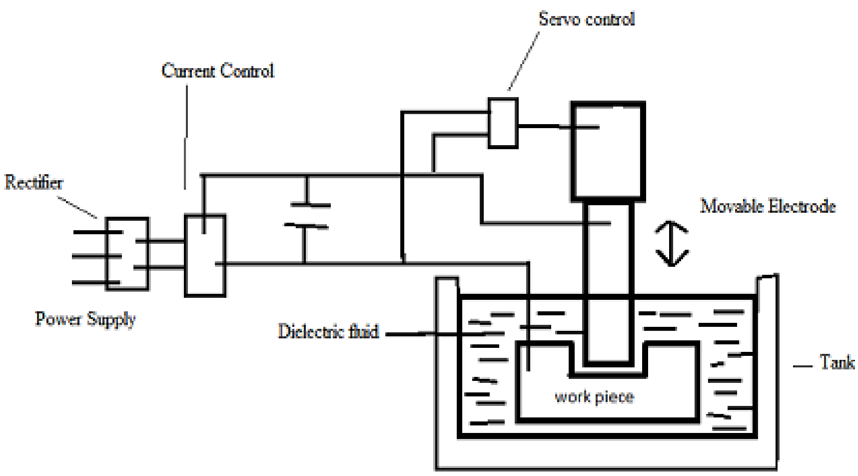

Fig. EDM Machining Process

Stainless steels have been widely used in various industries and domestic applications, because of their good corrosion resistance and mechanical properties [5]. Among them, stainless steel 316 is used for experimentation in this research. Due to low hardness, poor wear resistance of stainless steel, sensitive to pitting corrosion and stress corrosion are more while machining, thereby, the strength reduced and that can be avoided by surface coating [2–4]. Additionally, WEDM is able to cut stainless steel as thin as 0.004 inches. So in this research, a path to determine EDM machining parameters optimization for stainless steel 316 has been proposed and study aims towards the achieving the maximum metal removal rate, reduced electrode wear rate and surface roughness.

II. LITERATURE SURVEY

In 1997, Y.S Liao experimented on machining-parameters optimization of WEDM based on Taguchi approach by considering Material removal rate (MRR), gap width, surface roughness (SR), sparking frequency, average gap voltage and normal ratio. In 2001, Kuo-Ming and Pei-Jen studied the dimensional analysis for surface finish in EDM process by considering peak current, pulse duration, electrical polarity and property of the materials. In 2004, George et al used the composites and optimized Electrode wear rate and material removal rate. In 2005, Kun Ling worked by mixing Al powder in the dielectric fluid for improving the surface finish. In 2006, Lin Y investigated on the Machining characteristics and optimization of SKH57 high speed steel by Taguchi method. In 2009, Ei-Taweel investigated on the Multi-response optimization of EDM with Al-Cu-SiMiC Composite electrode. In 2010, Govindan and Joshi studied the Experimental categorization of material removal in dry electrical discharge drilling. In 2012, Harpreet Singh and Amandeep Singh worked on Effect of pulse-on-time and pulse-off-time on machining of AISI D3 die steel material using copper and brass electrode EDM. In 2014 - Selvakumar have also used Taguchi method to elevate WEDM of 5083-Aluminium Alloy. Pujari et al 2016, studied the generation of residual stress on the material by varying the operation parameters. Amrish and Senthilvelan in 2015 investigated the the effect and optimized the process parameter for the EDM for Titanium. Chengal et al in 2015 conducted experimentation in EDM for optimizing the process parameters using Grey Relational Analysis.

III. EXPERIMENTAL METHODOLOGY

This section includes the material selection and the methodology of implementation.

A. Material Selection

The entire EMD process depends on the materials used. So the selection of material and its thermal properties plays an important role. Chemical composition of work piece is very much essential for selecting the type of process and Stainless steel 316 is commonly used in industries like oil & petroleum, refining equipment, food processing equipment, pharmaceutical processing equipment, architectural, biomedical, etc, because it is having a good resistance to creep, excellent corrosion resistance, excellent weldability and easier to machine. Stainless steel 316 can be mechanically milled and sintered at 1173k and tends to work with low speed and constant feed rates. The specimens of 20mm x 10mm x10mm have been prepared for experimentation in this research. The chemical composition of stainless steel 316 is given in the Table 1.

Table 1 : Chemical Composition of Stainless Steel 316

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	V %	Mo %	Fe %
0.030	1.19	0.030	0.002	0.206	0.104	10.34	16.73	0.043	2.01	69.30

B. Optimization Methods

The optimization methods used in the research are as follow Taguchi and Anova.

Taguchi method : Taguchi method is commonly used optimization tool and is a powerful tool for the design optimization of high quality systems. It is efficient and systematic approach to optimize the performance, quality and cost. Also this method is insensitive to the variation of environmental conditions and other noise factors. Identifying the suitable process parameters is a complex and conflicting task. In this research, Optimization of EDM process parameters are used to achieve high quality machining without increasing cost by improving quality characteristics.

Anova : The analysis of variance (ANOVA) have also been performed to determine the significant and insignificant variables involved in the EDM process and to show their effects on the response characteristic. Then, the response curves have been plotted for raw data and S/N data in order to examine the parametric effects on the response characteristics. Finally, the optimal values are defined based on response curves. So that, the computational time can be reduced by eliminating the non-significant factors.

C. Experimental setup

The metal removal in EDM is due to melting and vaporization caused by the electric spark discharge generated by a pulsating direct current power supply between the negative electrodes which moves continuously over the positive electrode i.e. the work piece at very smaller gap. The research have been carried out to investigate the effect of peak current (Ip),wire feed (Wf), servo voltage (SV), pulse on time (Ton) and pulse off time (Toff) and the various levels taken for experimentation is given in the table 2.

Table 2 : EDM Process Parameters

Process Parameters	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Servo voltage (SV)	20	30	40	50	60
Arc gap µm	100	100	100	100	100
Discharge current (Ip)	90	110	130	150	170
Pulse-on time (Ton) µs	106	110	114	118	120
Pulse-off time (Toff) µs	30	35	40	45	50
Wire feed (Wf) mm/min	3	5	8	9	10
Electrode Diameter (mm)	10	10	10	10	10

Servo voltage (SV) is a potential difference between the power supply in a controlled manner which indirectly affects the material removal. Discharge current (Ip) is responsible for material removal. It contains energy for melting and evaporation. Pulse On time (Ton) is the duration of time in which the peak current flows in every cycle to remove the metallic particles from the work piece. Pulse Off time (Toff) is the period of time between the two pulse on time, during which the melted particle coagulate on to the work piece. Arc gap is the gap between the electrode and work piece in which the spark generate for eroding the metal from the work piece. Duty cycle (τ) is a ratio of the pulse on-time relative to the total cycle time expressed in percentage. The EDM machine specification used for the experimentation is given in the Table 3.

Table 3 : WEDM Characteristics

Characteristics	**Range**
Mechanism of process	Controlled erosion
Spark gap	10 - 125 µm
Spark frequency	200 – 500 kHz
Peak voltage across the gap	30 - 250 V
Maximum material removal rate	5000 mm3/min
Specific power consumption	2-10 W/mm3/min
Dielectric fluid uses	EDM oil, Kerosene and water with Glycol, silicon-based oil
Electrode material	Zinc alloy
MRR/TWR	0.1-10

IV. EXPERIMENTAL IMPLEMENTATION

The experimental studies were performed on a SODICK A535 WEDM machine tool. Zinc coated brass wire with 0.25 mm diameter (900 N/mm2 tensile strength) has been used in the experiments. The dielectric liquid is Kerosene and water with Glycol, silicon-based oil. The EDM machine used for the experimentation is shown in the Figure 2.

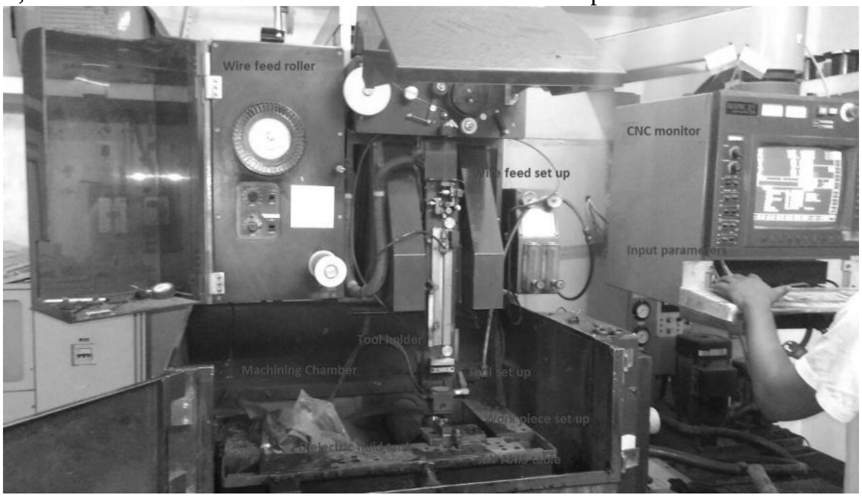

Figure 2 : EDM Machine

According to the taguchi design method, L9 Orthogonal array had been chosen for the optimization of the process. Five control factors were chosen at different levels by keeping the electrode diameter and the air gap as constant. Three response parameters such as MRR, Surface roughness along longitudinal and Surface roughness along transverse were measured. The output obtained is given in the Figure 3.

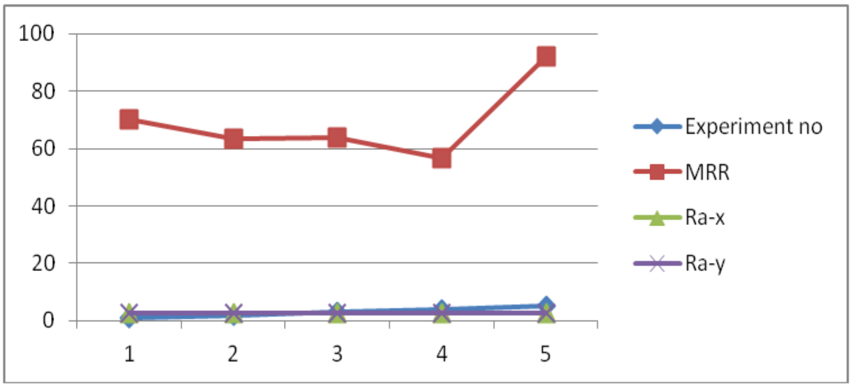

Figure 3 : Material Removal Rate and Roughness for different set of levels.

Due to the random nature of EDM, it is very essential to optimize the process parameters in EDM process. Conventional Taguchi method deals with single response optimization and needs to introduce multi response optimization technique. So Taguchi design of experiment with grey relational analysis methodology has been utilized to perform multi response optimization in this process. Grey relational technique is used for solving interrelationships among the multiple responses. In this analysis, the responses are transformed into the S/N ratio and then into normalized S/N ratio to distribute the data evenly.

V. RESULT

Signal to noise ratio with their normalized value for various response parameters are given in the Table 4.

Table 4 : S/N Ratio Table

Exp. No.	MRR mm^3/min	S/N	Norm.-S/N	Ra-x µm	S/N	Ra-Y µm	S/N
1	83.21	38.40351	0.856611	2.801	-8.94626	2.477	-7.87852
2	66.06	36.39877	0.632636	2.762	-8.82447	2.544	-8.11034
3	34.42	30.73622	0.542563	2.788	-8.90586	2.609	-8.32948
4	57.19	35.1464	0.492718	2.762	-8.82447	2.602	-8.30615
5	96.46	39.68695	0.999999	2.812	-8.98031	2.61	-8.33281
6	63.35	36.03493	0.591987	2.718	-8.68499	2.645	-8.44851
7	63.96	36.11817	0.601286	-8.6786	-8.25612	2.584	-8.24585
8	56.55	35.04865	0.481797	-8.87152	0.639414	2.549	-8.1274
9	92.16	39.29085	0.955747	-8.97103	0.969258	2.625	-8.38259

The plot obtained from the MINITAB software for the different level of input parameters are shown I the Figure 4.

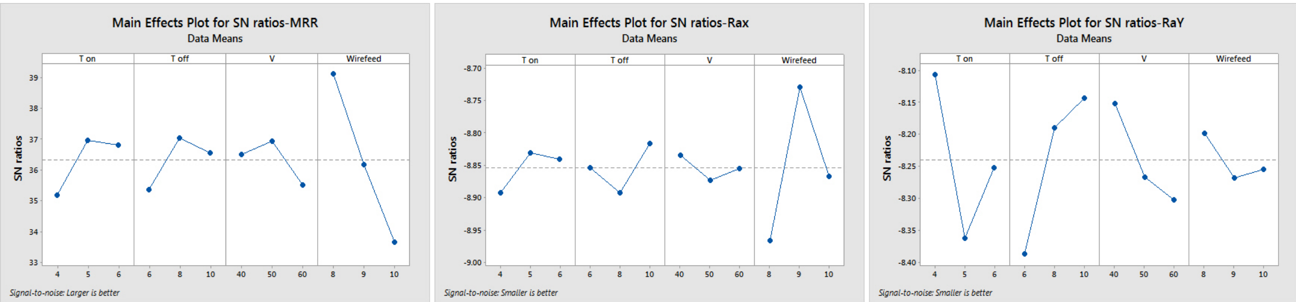

Figure 4 : Plot of S/N Ratio Vs Different Levels of Input Parameters

From the Figure 4, for the response of MRR the Wire Feed is a dominating factor, for the response of RaX, the Wire Feed is a dominating factor and for the response of RaY the Pulse On Time is a dominating factor.

VI. CONCLUSIONS

Optimization of wire EDM process on stainless steel 316 using Taguchi method-based Grey analysis has been studied in this research. Wire EDM is a complex machining process having many factors influencing the output and the factors considered are pulse on time, pulse off time, gap voltage, wire feed for obtaining multiple performance characteristics such as material removal rate, surface roughness. The highest max–min grade value shows that the pulse off time has the most influent parameter on determining response characteristics. The values of optimum electrical process parameters among the existing parameter combinations are pulse on time 5 µs, pulse off time 8 µs, gap voltage 60 V, wire feed rate 8 mm per min has given the better multiple response characteristics.

REFERENCES

[1] Pandey P. C. and Shan H. S, Modern Machining Processes, Tata McGraw-Hill Publishing Company, 1980, pp. 79-80.
[2] Li, L.; Dong, C. F.; Xiao, K.; Yao, J. Z.; Li, X. G. Effect of pH on Pitting Corrosion of Stainless Steel Welds in Alkaline Salt Water. Constr. Build. Mater. 2014, 68, 709−715.
[3] Sui, R. J.; Liu, Y.; Wang, W. Q.; Qu, Y. P.; Su, C. G.; Chang, F. Failure Analysis of Austenitic Stainless Steel Pipes in Amine Liquid Regeneration Unit of a Desulfurizer. Eng. Failure Anal. 2015, 57, 164−170.
[4] Zhiming, L.; Laimin, S.; Shenjin, Z.; Zhidong, T.; Yazhou, J. Effect of High Energy Shot Peening Pressure on the Stress Corrosion Cracking of the Weld Joint of 304 Austenitic Stainless Steel. Mater. Sci. Eng, A 2015, 637, 170−174.
[5] Hsu, C.-H.; Huang, K.-H.; Lin, Y.-H. Microstructure and Wear Performance of Arc-deposited Ti−N-O Coatings on AISI 304 Stainless Steel. Wear 2013, 306 (1−2), 97−102.

[6] Yan, Mu-Tian & Chiang,Tsung-Liang , Design and experimental study of a power supply for micro-wire EDM, Int J Adv Manuf Technol (2009) 40.

[7] Norliana Mohd Abbas, Darius G. Solomon, Md. Fuad Bahari, A review on current research trends in electrical discharge machining (EDM), International Journal of Machine Tools & Manufacture 47 (2007) .

[8] K.H. Ho, S.T. Newman, State of the art electrical discharge machining (EDM), International Journal of Machine Tools & Manufacture 43 (2003).

[9] D.T Pham, S.S Dimov,Bigot.S, A.Irvanov, K.Popov, Micro-EDM-recent developments and research issues., International Journal of Machine Tools & Manufacture 149(2004).

[10] Y.S. Liao,: Y.Y. Chu and M.T. Yan: Study Of Wire Breaking Process And Monitoring Of WEDM, Int. J. Mach. Tools Manufact. Vol. 37, No. 4, pp. 555-567,1997

[11] R. E. Williams and K. P. Rajurkar, Study of wire electrical discharged machine surface characteristics, Journal of Materials Processing Technology,28(1991) pp. 127-138

[12] S.S Mohapatra, Amar pattnaik,Optimization of WEDM process parameters using Taguchi method, International Journal of Advanced manufacturing Technology (2006)

[13] P.J Ross. Taguchi Techniques For Quality Engineering. New York, McGraw- Hill ,1984

[14] Y.S Liao , J.T.Huang, A study on the machining parameter optimization of WEDM, Journal of Material Processing Technology,71(1997) pp. 487-493.

[15] Pujari Srinivasa Rao, Koona Ramji, Beela Satyanarayana, “Effect of wire EDM conditions on generation of residual stresses in machining of aluminum 2014 T6 alloy. Alexandria Engineering Journal, Volume 55, Issue 2, June 2016, Pages 1077-1084.

[16] D. Amrish Raj, T. Senthilvelan, "Empirical Modelling and Optimization of Process Parameters of machining Titanium alloy by Wire-EDM using RSM", Materials Today: Proceedings, Volume 2, Issues 4–5, 2015, Pages 1682-1690

[17] V. Chengal Reddy, N. Deepthi, N. Jayakrishna, "Multiple Response Optimization of Wire EDM on Aluminum HE30 by using Grey Relational Analysis", Materials Today: Proceedings, Volume 2, Issues 4–5, 2015, Pages 2548-2554.

