International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Optimization of WEDM Parameters using Taguchi and ANOVA Method

Mohit Datt†* and Daljinder Singh†

†Chandigarh Group of Colleges, Landran (Punjab), India

Accepted 18 Dec 2015, Available online 22 Dec 2015, **Vol.5, No.6 (Dec 2015)**

Abstract

Wire-cut Electrical Discharge Machining (WEDM) is extensively used in machining of conductive materials producing intricate shapes with high accuracy. This study exhibits that WEDM process parameters can be altered to achieve betterment of Material removal rate (MRR), Surface Roughness (SR). The objective of our project is to investigate and optimize the potential process parameters influencing the MRR, SR while machining of EN-31 using WEDM process. This work involves study of the relation between the various input process parameters like Wire Speed, Flushing Pressure and Gap Voltage. Based on the chosen input parameters and performance measures L-9 orthogonal array is selected to optimize the best suited values for machining.

Keywords: *Wire Speed, Flushing Pressure, Gap Voltage, MRR, SR, Orthogonal array*

Introduction

Electrical Discharge Machining, EDM is one of the most accurate manufacturing processes available for creating complex or simple shapes and geometries within parts and assemblies. EDM works by eroding material in the path of electrical discharges that form an arc between an electrode tool and the work piece. EDM manufacturing is quite affordable and a very desirable manufacturing process when low counts or high accuracy is required. Turnaround time can be fast and depends on manufacturer back log. The EDM system consists of a shaped tool or wire electrode, and the part. The part is connected to a power supply. Sometimes to create a potential difference between the workpiece and tool, the work piece is immersed in a dielectric (electrically non conducting) fluid which is circulated to flush away debris. The cutting pattern is usually CNC controlled. Many EDM machine electrodes can rotate about two-three axis allowing for cutting of internal cavities. This makes EDM a highly capable manufacturing process.

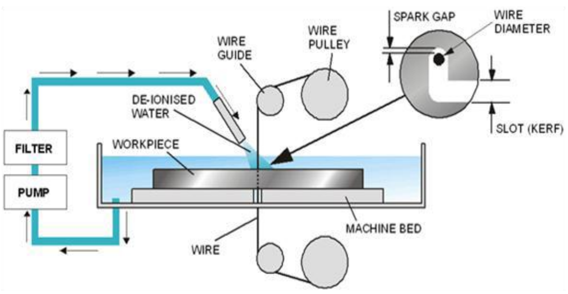

Fig.1 Schematic Diagram of WEDM System

*Corresponding author: **Mohit Datt**

The Spark Theory on a wire EDM is basically the same as that of the vertical EDM process. In wire EDM, the conductive materials are machined with a series of electrical discharges (sparks) that are produced between an accurately positioned moving wire (the electrode) and the workpiece. High frequency pulses of alternating or direct current is discharged from the wire to the workpiece with a very small spark gap through an insulated dielectric fluid (water). Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less. The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required.

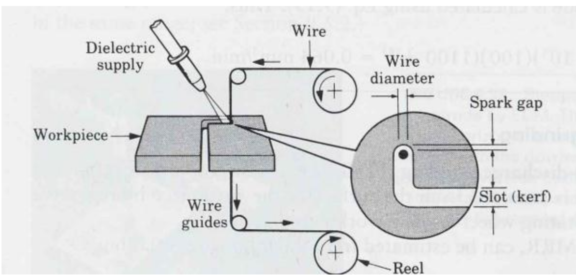

Fig.2 Principle of WEDM

Steps in Taguchi methodology

Taguchi proposed a standard 8-step procedure for applying his method for optimizing any process:

Step-l: Identify the main function, side effects, and failure mode.
Step-2: Identify the noise factors, testing the conditions, and quality characteristics.
Step-3: Identify the objective function to be optimized.
Step-4: Identify the control factors and their levels.
Step-5: Select the orthogonal array matrix experiment.
Step-6: Conduct the matrix experiment.
Step-7: Analyze the data; predict the optimum levels and the performance.
Step-8: Perform the verification experiment and plan the future action.

Orthogonal Arrays

The Taguchi Robust Design method uses a mathematical tool called Orthogonal Arrays (OAs) to study a large number of process variables with a small number of experiments. OAs is fractional factorial designs which are symmetrical sub-sets of all combinations of treatments in the corresponding full factorial designs (that is, when all levels of all the factors are taken into consideration one by one). If experiments are conducted by taking one level of each parameter at a time, the number of experiments will run into 67 thousands, making it a very time consuming and expensive process. Another major disadvantage of one-parameter-at-a-time approach is that it fails to consider any possible interaction between the parameters. An interaction is the failure of one parameter to produce the same effect on the response at different levels of another parameter.

Analysis Of Variance (ANOVA)

Taguchi suggests two different routes to carry out complete analysis of the experimental data. In the first approach, results of a single run or the average of repetitive runs are processed through main effect and ANOVA analysis of the raw data. The second approach, which Taguchi strongly recommends, is to use Signal-to-Noise (S/N) ratios for the same steps of the analysis. The S/N ratio is generally represented by η and is a concurrent quality metric linked to the loss function. By maximizing the S/N ratio, the loss associated with the process can be minimized. The S/N ratio determines the most robust set of operating conditions from variation within the results.

Literature Review

J. T. Huang a & Y. S. Liao experimented (2013) optimization of machining parameters of Wire-EDM based on Grey relational and statistical analyses it is concluded that table feedrate and Ton have the main influence in MRR, and Ton has a significant influence on G and Ra.

P. Abinesh , Dr. K. Varatharajan , Dr. G. Satheesh (2014) Kumar study exhibits that WEDM process parameters can be altered to achieve betterment of Material removal rate(MRR),Surface Roughness (SR) and Electrode Wear. The objective of our project is to investigate and optimize the potential process parameters influencing the MRR, SR and Electrode Wear while machining of Titanium alloys using WEDM process. This work involves study of the relation between the various input process parameters like Pulse-on time(Ton), Pulse off time(Toff), Pulse Peak Current(IP), Wire material and Work piece material and process variables. Based on the chosen input parameters and performance measures L-16 orthogonal array is selected to optimize the best suited values for machining for Titanium alloys by WEDM.

R.Pandithurai, I. Ambrose Edward (2014) lustrates that WEDM involves complex physical and chemical process including heating and cooling. The electrical discharge energy affected by the spark plasma intensity and the discharging time will determine the crater size, which in turn will influence the machining efficiency and surface quality. This paper presents an effective approach to optimize process parameters for Wire electro discharge machining (WEDM).WEDM is extensively used in tool and die industries. Precision and intricate machining are the strengths. While machining time and surface quality still remains as major challenges. The main objective of this study is to obtain higher material removal rate (MRR) and lower surface roughness (SR). Ton, T off, Gap voltage and wire feed rate are the four control factors taken each at various levels. The genetic algorithm optimization tool is used to find the factors level that create a low surface roughness in WEDM.

R.Nagaraja, K.Chandrasekaran, S.Shenbhgaraj (2015) presents an investigation on the optimization of machining parameters in WEDM of bronze-alumina MMC. The main objective is to find the optimum cutting parameters to achieve a low value of Surface roughness and high value of material removal rate (MRR). The cutting parameters considered in this experimental study are, pulse on time (Ton), pulse off time (Toff) and wire feed rate. The settings of cutting parameters were determined by using Taguchi experimental design method. An L9 orthogonal array was chosen. Signal to Noise ratio (S/N) and analysis of variance (ANOVA) was used to analyze the effect of the parameters on surface roughness and to identify the optimum cutting parameters. The contribution of each cutting parameters towards the surface roughness and MRR is also identified. The study shows that the Taguchi method is suitable to solve the stated problem with minimum number of trails as compared with a full factorial design.

Problem Formulation

WEDM has extensive use in the industries for the manufacture of dies and moulds. En-31 (high carbon alloy steel) material is used as workpiece for tool and dies manufacturing. So many parameters affecting the working of wedm some important factors affecting the performance of WEDM are wire speed, flushing pressure and gap voltage

Parameters

1. Input Parameters
Wire Speed
Flushing Pressure
Gap Voltage
2. Output Parameters
MRR(mm^3/min) (Metal removal rate)
Surface Roughness (R_a)

Objectives

- To study the Wire Electrical Discharge Machining process.
- To understand the effect of parameters Wire speed, Flushing pressure and Gap voltage.
- To optimize the effect of parameters MRR and surface roughness of material EN31.

Experimentation

The Elpuls 12 (WEDM) Machine

The ELPULS 12 Wire EDM (WEDM) was used to carry out the experiments. The WEDM experiments were conducted in ELPULS 12 machine using 0.25 mm brass wire as the tool electrode.

Fig.3 Pictorial View of WEDM

EN-31 Material

EN 31, High strength temperature resistant (HSTR) alloy, was used for the present investigation.

Table 1 Chemical Composition of EN 31

C%	Mn%	Si%	P%	S%	Cr%	Cu%
0.9267	0.5267	0.3464	0.01978	0.03060	1.418	0.1183

Fig.4 EN 31 Steel

EN31 is a high carbon Alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance. By its character this type of steel has high resisting nature against wear and can be used for components which are subjected to severe abrasion, wear or high surface loading.

Conduct of experiment

Selecting the input parameters and performance measures has to be determined before performing the experiments. In this work, the behaviors of three control factors were studied. These parameters with their levels are listed in Table.

Table 2 Control Factors and There Levels

Controlled parameters	Levels			Observed Values
	L_1	L_2	L_3	
Wire Speed (m/min)	7	10	13	1. Material Removal Rate (mm^3/min) 2. Surface Roughness (R_a)
Flushing Pressure (kgs/m^2)	8	16	24	
Gap Voltage (volts)	40	50	60	

Experiments were conducted using L9 Orthogonal Array shown in Table4.5 to find the effect of process parameters on the MRR. The experiments were done on EN31 Steel. High speed brass wire was used as tools. The rate of cutting speed for each work piece and tool materials were collected in same experimental conditions. After performing experiment MRR value is recorded in each experiment shown in Table.

Table 3 Taguchi's L9 orthogonal array with values of levels

Experiment No.	Wire Speed	Flushing Pressure	Gap Voltage
1	7	8	40
2	7	16	50
3	7	24	60
4	10	8	50
5	10	16	60
6	10	24	40
7	13	8	60
8	13	16	40
9	13	24	50

Table 4 TheL9 Orthogonal Array with Performance

Experiment No.	Wire Speed	Flushing Pressure	Gap Voltage	MRR	R_a
1	7	8	40	4.805	4.580
2	7	16	50	3.700	5.270
3	7	24	60	5.640	4.025
4	10	8	50	3.649	6.890
5	10	16	60	5.434	5.399
6	10	24	40	6.541	4.657
7	13	8	60	3.404	5.670
8	13	16	40	4.228	4.001
9	13	24	50	4.104	5.080

Results and Discussion

Analysis of machining variables

The present analysis includes Taguchi's method based on parametric optimization technique to quantitatively determine the effects of various machining parameters on the quality characteristics of EDM process and to find the optimum parametric condition for obtaining optimum machining criteria. In this analysis, the performed parametric design of experiment is based on the selection of an appropriate standard orthogonal array. The analysis of signal-to-noise (S/N) ratio and ANOVA were carried out to study the relative influence of the machining parameters on the MRR of the Wire cut EDM machined material. Based on S/N ratio and ANOVA analysis, the optimal setting of the machining parameters for machined Material removal rate was obtained. Table shows the contribution factor of the parameters and the error which is 0.1318.

Table 5 Analysis of variance (ANOVA) for S/N Ratio w.r.t MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Contribution
Wire Speed	2	2.5675	2.5675	1.2837	19.49	0.049	24.85
Flushing Pressure	2	3.3783	3.3783	1.6891	25.64	0.038	43.40
Gap Voltage	2	3.0372	3.0372	1.5186	23.05	0.042	30.58
Error	2	0.1318	0.1318	0.0659			1.18
Total	8	9.1147					

The tables include ranks based on delta statistics, which compares the relative magnitude of effects. The delta statistic is the highest average minus the lowest average for each factor. Minitab assigns ranks based on delta values in descending order; the highest delta value has rank. 1 and rank 2 is assigned to the second highest, and so on. The ranks indicate the relative importance of each factor to the response.

Table 6 Analysis of variance (ANOVA) for S/N Ratio w.r.t SR

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Contribution
Wire Speed	2	1.6685	1.6685	0.8342	19.41	0.049	25.80
Flushing Pressure	2	2.0374	2.0374	1.0187	23.70	0.040	31.51
Gap Voltage	2	2.6740	2.6740	1.3370	31.11	0.031	41.36
Error	2	0.0860	0.0860	0.0430			1.33
Total	8	6.4658					25.80

Table 7 Response Table for Signal to Noise Ratio Larger is better (MRR)

Level	Wire Speed	Flushing Pressure	Gap Voltage
1	13.34	11.84	14.16
2	14.09	12.86	11.62
3	11.81	14.53	13.46
Delta	2.28	2.70	2.53
Rank	3	1	2

Table 8 Response Table for Signal to Noise Ratio Smaller is better (SR)

Level	Wire Speed	Flushing Pressure	Gap Voltage
1	-13.25	-15.02	-12.87
2	-14.92	-13.71	-15.11
3	-13.74	-13.19	-13.94
Delta	1.67	1.83	2.23
Rank	3	2	1

Analysis of variance (ANOVA) is performed and signal-to-noise (S/N) ratio will be determined to know the level of importance of the machining parameters.To obtain the optimal machining performance the higher the better quality characteristics for MRR.As can be seen from Table (above), the MRR is most significantly influenced by the Flushing Pressure followed by the Gap Voltage. The respective values of these parameters are 2.70 and 2.53. After finding all the observation as given in Table 5.1 & 5.2, S/N ratio are calculated and graph for analysis is drawn by using Minitab 16 software. The S/N ratio for MRR is calculated on Minitab 16 Software using Taguchi Method.

The S/N response graph for Material Removal rate is shown in Fig 5.1. The greater average S/N ratio corresponds to the max MRR. From the S/N response graph Fig5.1, it is concluded that the optimum parametric combination isWire Speed(10), Flushing Pressure(24), and Gap Volatage (40). In other words, it is this combination of parameters that gives the max MRR for the machined material.

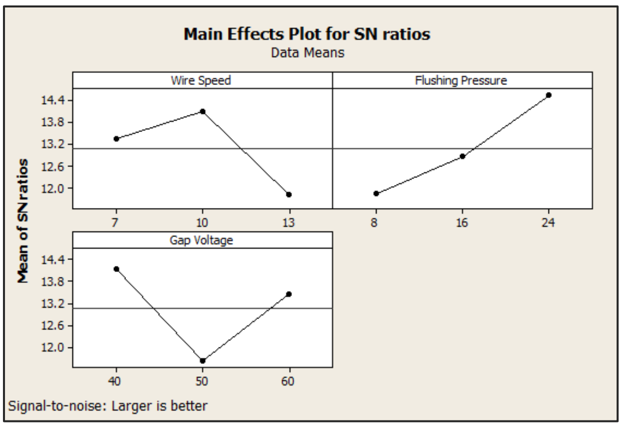

Fig.5 S/N Ratio for MRR

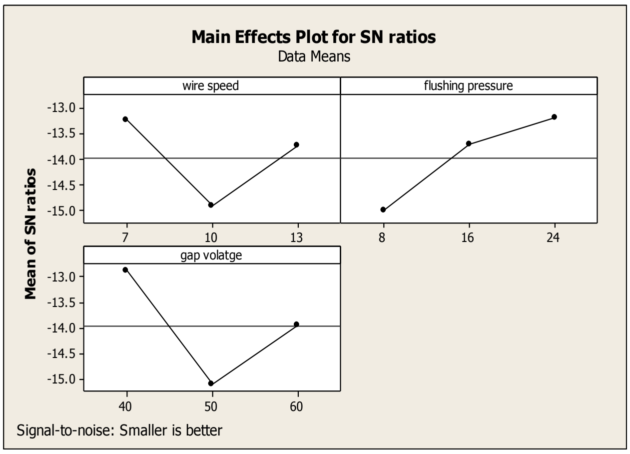

Fig.6 S/N Ratio for SR

Conclusion

From the experimental results, S/N ratio and ANOVA analysis and predicted optimum machining parameters, the following conclusions are drawn:

1. From ANOVA Table 5.1 and Response table for Signal to Noise, based on the ranking it shows that Flushing Pressure has a greater influence on the MRR followed by Gap Voltage and Wire Speed had the least influence on MRR.
2. From ANOVA Table 5.4 and Response table for Signal to Noise, based on the ranking it shows that Gap voltage has a greater influence on the SR followed by Flushing pressure and Wire Speed had the least influence on SR.
3. The optimal parameters from the view point of maximum Material removal rate are Wire Speed (10), Flushing Pressure (24), and Gap Voltage (40) which yields an outcome as 6.541 mm^3/ min.
4. The ideal parameters for Surface roughness are Wire Speed (7), Flushing Pressure (24), and Gap Voltage (40) shows a result of 3.99 Ra.
5. The most favorable parameters for compromise between SR and MRR are Wire Speed (7), Flushing Pressure (24), and Gap Voltage (60) which presents a values 4.025Ra and 5.640 mm^3/ min respectively.
6. The validation experiment confirmed that the error was less than 1.18 % between equation and actual value

Future scope

1. We can conduct this on different materials like C-45, D2 steel, En-8, En-9 etc.
2. We can perform this on different parameters like Pulse-ON, Pulse-OFF, Wire tension, Peak current, Wire feed rate etc.
3. We can conduct this process with the help of different wire electrode like Steel core wire Moly wire, Tungsten wire, Cryogenic treated wire.

References

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

Ahmet Hascalık, (2007) Electrical discharge machining of titanium alloy (Ti–6Al–4V) Applied Surface Science 253 9007–9016.

Amoljit Singh Gill, Amit Thakur, Sanjeev Kumar (2012) Effect of Deep Cryogenic Treatment on the Surface Roughness of OHNS Die Steel after WEDM International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11

A Prapmetric Optimisation Using Taguchi Method International Journal Of Advanced Engineering Sciences And Technologies Vol No. 6, Issue No. 1, 041 – 048

Bijendra Diwakar, Vedansh Chaturvedi and Jyoti Vimal (July 2012), Application of taguchi approach for optimization of CNC wire electrical discharge machining process parameters.

D.Scott, S. Boyna, and K.P. Rajurkar,.(1991)Analysis and optimization of parameter combinations in WEDM. Int. J. Prod. Res, 29, 2189–2207 (1991).

Farnaz Nourbakhsh,(2012) Machining ability of WEDM of Titanium, Industrial and Management Systems

H S Payal (October 2008) Analysis of electro discharge machined surfaces of EN-31 tool steel.

Ko-Ta Chiang ,Fu-Ping Chiang (2006) Timization of the WEDM process of particle-reinforced material with multiple performance characteristics using grey relational analysis Journal of Materials Processing Technology 180 (2006) 96–101

Harshadkumar C. Patel, Dhaval M. Patel, Rajesh Prajapati (July-August 2012), Parametric Analysis And Mathematical Modelling Of MRR And Surface Roughness For H-11 Material On Wire Cut EDM By D.O.E Approach Vol. 2, Issue4, pp.1919-1924