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STUDY THE EFFECTS OF VARIOUS PARAMETRIC FACTORS ON MATERIAL REMOVAL RATE (MRR) OF WEDM FOR EN31 STEEL

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ABSTRACT

There is a great demand of accurate machined and complex shapes in the manufacturing industry the ordinary machining processes aren't suitable for it. So, these machining processes are being replaced by non-conventional machining processes. In this work I have considered Wire Electric Discharge Machining, since it is a non- conventional machining process which can generate highly accurate machined complex and complicated shapes with greater accuracy in short period of time as compared to ordinary machining processes. In the present dissertation, an experimental study has been done to enhance the Material Removal Rate (MRR) for machining of EN31 steel on WEDM using Taguchi's Method. The four process parametric factors that have been selected for the study are pulse on time, pulse off time, wire feed and wire tension. In the present study Taguchi's L9orthogonal array is used to optimize the values for cutting EN31 steel by WEDM. The experiment is carried out on ELECTRONICA SPRINTCUT WEDM machine using brass wire of 0.25mm diameter and distilled water as the dielectric fluid.

I. INTRODUCTION

Wire Electrical Discharge Machining (WEDM) is a non-conventional machining process in which there is no any direct contact between tool and work piece. In this type of machining a form of energy is used for removing unwanted materials for achieving accurate shapes which can't be obtained by the means of a conventional machining process. It is a thermo-electric process in which material is detached from the job by developing a series of electric sparks from a D.C power across the gap between the tool (wire electrode) and the work piece. The work piece and the wire electrode are saturated in dielectric fluid usually distilled water. The dielectric fluid also acts as a coolant.

WEDM can only uses for the materials which are electrically conductive such as steel, stainless steel, tool steel, copper, graphite and aluminium, and also the exotic space-age alloys like hastaloy, inconel, waspaloy, carbide, polycrystalline diamond compacts titanium, and ceramics (conductive) etc. It is used to machine work piece of any hardness because direct contact between the work piece and the tool (wire electrode) doesn't exist.

Literature review consists of **Williams and Rajurkar (1991)** carried out experiments on WEDM to study surface characteristics of the Wire Electrical Discharged machined surfaces. **Puri and Bhattachryya (2003)** used Taguchi methodology by selecting thirteen process parameters as control factors with three levels of each using Taguchi's orthogonal array L27 to determine the process parameters that affect the response parameters such as surface roughness values, and average cutting speed due to wire lag. **Huang and liao (2003)** determined the optimal parameters setting of WEDM process with the help of grey relational and S/N ratio analysis. He concluded that the surface roughness and MRR are easily affected by the table feed rate and pulse on time. **Sarkar et al. (2005)** did an experimental work on a work piece of ɤ-titanium aluminide alloy by developing the mathematical models to determine the surface finish, cutting speed and dimensional inaccuracy with respect to different process parameters. After that **Jasvir Singh and Kulwinder Kumar (2014)** investigated the effect of Wire EDM process parameters on EN8 steel's surface roughness. The experimental work was done with the help of Taguchi's L27 OA and using copper wire as an electrode. The process parameters selected for the investigation were pulse on peak current, time, wire feed, pulse off time and wire tension. **Vikrant Aggarwal and Rajeev Kumar (2015)** investigated the effects of cutting parameters on EN31 with WEDM using software MINITAB17. The parameters selected were pulse on time, pulse off time, wire feed ,peak current andservo voltage. **MohdAtif et al.,(2016)** optimized process parameters on WEDM for EN31using Taguchi's L9 OA and ANOVA analysis. The process response selected was Surface

Roughness. The levels of WEDM parameter for surface roughness recommended by him are Pulse ON (TON) 115µs, Pulse OFF (TOFF) 40µs and Peak Current (Ip) is 150A.

II. EXPERIMENTATION

2.1 Taguchi Procedure for Experimental Design and Analysi

Taguchi guided (Roy, 1990) two different methods to carry out the complete experiment. First, the standard approach, where the outcomes of a single run or the average of repetitive continuously runs is processed through main effect and ANOVA analysis (Raw data analysis). The second method of approach which Taguchi strongly guided for multiple runs is to use signal- to- noise ratio (S/N) for the same steps in the examination. The S/N ratio is a concurrent quality metric linked to the loss function (Barker, 1986). By more the S/N ratio, the loss associated can be minimized. The S/N ratio calculate the most powerful set of operating conditions from variation within the results. The S/N ratio is treated as a response (transform of raw data) of the experiment. Taguchi recommends (Ross, 1988) the use of outer OA to force the noise variation into the experiment i.e. the noise is intentionally introduced into experiment. However, processes are often times subject to many noise factors that in combination, strongly influence the variation of the response. For extremely „noisy" systems, it is not generally necessary to identify specific noise factors and to deliberately control them during experimentation. It is sufficient to generate repetitions at each experimental condition of the controllable parameters and analyze them using an appropriate S/N ratio (Byrne and Taguchi, 1987)

In this thesis work, the raw data analysis (ANOVA) and S/N data examination have been conducted. The effects of the chosen WEDM process parameters on Material Removal Rate (MRR) have been investigated with the help of the plots of the main effects based on raw data. The optimum condition for Material Removal Rate (MRR) has been established using S/N data analysis aided by the raw data analysis. In selecting an appropriate OA, the pre-requisites are (Ross, 1988; Roy, 1990):

- Selection of process parameters and/or interactions to be evaluated
- Selection of number of levels for the selected parameters

2.2 Machine Tool

The experiments were carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT734) of Electronica Machine Tools Ltd.The WEDM machine tool has the following specifications:

Design	: Fixed column, moving table
Table size	: 440 x 650 mm
Max. work piece height	: 200 mm
Max. work piece weight	:500 kg
Main table transverse(X, Y)	: 300, 400 mm
Auxiliary table transverse(u, v)	:80, 80 mm
Wire electrode diameter	:0.25 mm(Standard)
Generator	: ELPULS-40A DLX
Controlled axes	:XY,U,V simultaneous /independent
Interpolation	:Linear &Circular
Least input increment	:0.0001mm

Least command input(X,Y, u,v)	:0.0005mm
Input Power supply	: 3 phase,AC415 V, 50 Hz
Connected load	: 10 KVA
Average power consumption	:6 to7 KVA

2.3 Work piece material:

EN 31 steel is a high Carbon alloy steel having more hardness with high compressive strength and abrasion resistance. EN steel is made as per European Standard for series of such high carbon steel alloy like EN 8, EN19, EN24, EN31 etc.

S.No.	Element	%age of composition
1.	Carbon (C)	0.90 - 1.10
2.	Silicon (Si)	0.10 - 0.35
3.	Manganese (Mn)	0.30-0.75%
4.	Phosphorus (P)	0.05 max
5.	Sulphur (S)	0.05 max
6.	Chromium (Cr)	1.00 - 1.501

Chemical Composition of EN-31 Tool Steel

The physical properties of EN31 steel alloy steel are given in the following table:

Density (g/mm^{3})	Melting Point
0.007810	1426˚C

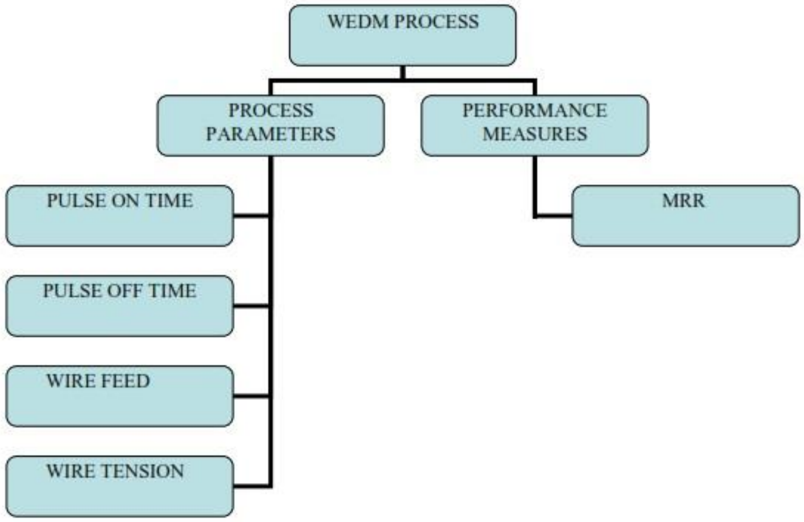
Physical properties of Work piece

In the Preparation of Specimens A blank of EN31 alloy steel plate with dimensions 250mm x 80mm x 10mm is mounted on the ELECTRONICA SPRINTCUT WEDM machine tool (Figure 4.1) and specimens of dimensions 15mm x 74mm x10mm are cut from the plate using a program designed using AutoCAD. The blank mounted on the WEDM machine used for cutting the specimens

2.4 Measurement of Parameters

The experiments were accomplished on an Electronica Sprintcut WEDM machine. The procedure followed for cutting on WEDM is :

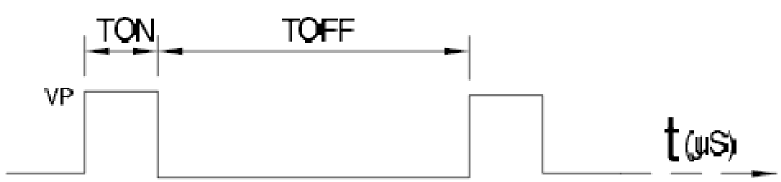
- The wire was held vertical using vertical block.
- The work piece was fixed and clamped on the work table of WEDM.
- A reference point was made on the work piece for setting the work co-ordinate system (WCS). The reference point was defined using the ground edges of the work piece.
- The program was designed using AutoCAD for cutting a profile of 15mm x 74mm x 10 mm from the work piece.
- The Selection of Process Parameters, After studying the literature analysis, the process parameters selected in the present work are Pulse on time, Pulse off time, wire feed and wire tension.



Shows the flowchart of WEDM process.

Pulse on Time
The pulse on time is denoted byTonand its unit is microseconds (μs). It is the time interval for which the current flowsin each cycle (Figure5.3). During pulse on time the voltageVP, is applied across gap between the anode and cathode. The range of pulse on time (Ton) available on the machine is 100-131.

Pulse off Time
The pulse off time is denoted byToff and its unit is microseconds (μs). The voltage is not present during pulse on time. The range of pulse off time (Toff) available on the machine tool is 40-63.



Series of Electrical Pulses between the Electrode Gap

Wire Feed
Wire feed is the speed at which the wire-electrode is fed along the wire guide path for sparking. The range of wire feed available on the present machine is1–15 m/min.

Wire Tension
Wire tension may be defined as the stretching of the wire between the lower and upper wire guides. It is the gram-equivalent load with which the continuously fed wire is kept straight between the wire guides. The range of wire tension available on the machine is 1-15.

Material Removal Rate
MRR value is obtained by the following equation:
$MRR = (Wb–Wa)/(T_m \times \rho)(mm^3/sec)$
Where Wb is weight before machining,
Wa isweight after machining,

T_m is machining time and

ρ is the density of work piece in g/mm^3.

Process parameters	Symbols	Units	Range of Parameters
Pulse on Time	Ton	µs	100-131
Pulse off Time	Toff	µs	40-63
Wire Feed	WF	m/min	1-15
Wire Tension	WT	Gram	1-15

Process Parameters with their Symbols and Ranges

III. EXPERIMENTAL RESULTS

The aim of the pilot experiments is to find the variations in the MRR due to WEDM process parameters. It is also used to find the range of different parameters for the experimental design methodology used in the present work. The pilot experiments were done on ELEKTRA SPRINTCUT WEDM machine (Figure 5.1). The input parameters taken during the experimentation are pulse on time (Ton), pulse off time (Toff), wire feed (WF) and wire tension (WT).

The process parameters shown below were kept constant during the experiments

Work Material	:	Alloy Steel EN31
Cutting Tool	:	Brass wire of 0.25 mm dia
Servo Feed	:	2100units
Flushing Pressure	:	1unit
Peak Voltage	:	2units
Height of work piece	:	4mm

Constant parameters

According to design of experiment and orthogonal array L9 experiments were performed on EN 31 and the MRR is measured as shown in following table.

S. No.	Toff(µs)	Toff(µs)	WF (m/min) (m/min)	WT (grams)	MRR (mm^3/sec) (mm3/sec.)
1	124	50	3	6	5.9947
2	124	52	4	8	6.3418
3	124	54	5	10	6.1617
4	125	50	4	10	7.3787
5	125	52	5	6	6.9885

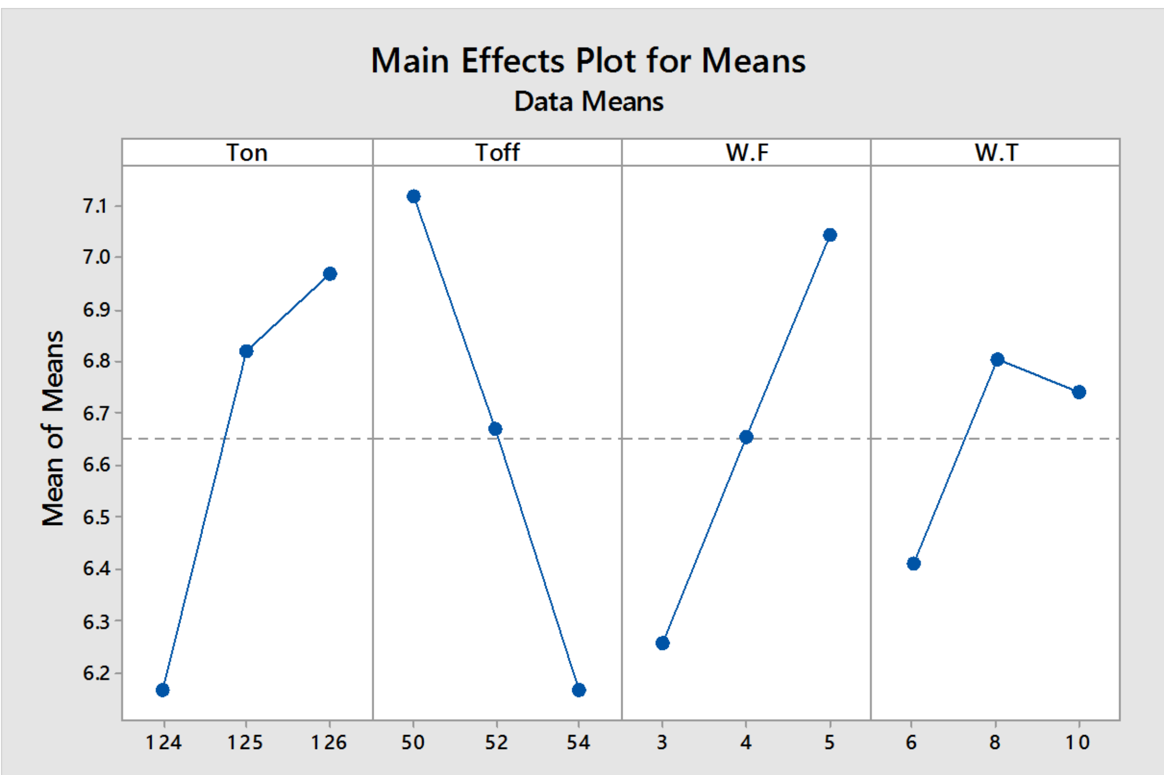
6	125	54	3	8	6.0915
7	126	50	5	8	7.9851
8	126	52	3	10	6.6837
9	126	54	4	6	6.2469

Results of the L9 Orthogonal Array

3.1 Analysis of Raw Data and S/N ratios

The purpose of the ANOVA is to study how MRR is affected by process parameters. The analysis shows the contribution of different machining parameters and the response of material removal rate (MRR) during cutting EN31. Table shows that process parameters pulse on time, pulse off time, wire feed and wire tension are responsible factors and have influence on MRR while machining EN31 on WEDM. According to the analysis of variance (ANOVA), the pulse off time is the most significant factor for MRR. The effect of pulse on time is remarkable and wire feed has significant influence while wire tension has less effect on MRR as compared to others during machining EN31 on WEDM. The response and the S/N ratio graph shows that all four parameters had some effect on MRR. It is observed from the response and S/N ratio graphs, that pulse off time and pulse on time have a strong influence on MRR and whereas wire feed and wire tension have a weak influence on MRR.

The MRR and S/N ratios data in these graphs can are used to find the optimal set of parameters for the experiment. The graphs indicate the optimal levels of MRR, and S/N ratio. The highest magnitude values are chosen for the MRR



3.2 Regression Analysis

To understand the Wire Electric Discharge Machining process, experimental results were used to find the mathematical models. In the present dissertation, **MINITAB 17,** mathematical software has been used for the determining regression constants and exponents. Linear regression models investigate the linear relationship between a predictor and response. Both the response and the predictor are continuous variables. The proposed first order model regression equation for MRR that is developed from the functional relationship is as follows:
Regression Analysis: MRR versus Pulse on Time, Pulse off Time, Wire feed, Wire tension

The regression equation for (MRR) is:
MRR = -33.6 + 0.4029 Ton - 0.2382 Toff + 0.3942 W.F + 0.0828 W.T

The predicted values are determined from the above equation for each factor at each level. The predicted values are also called fitted values. After determining the predicted values, the residuals can be determined. Table shows the fitted values and residuals for each factor at each level for MRR and Ra.

Predicted MRR	Actual MRR	Deviation
6.129	5.9947	-0.1343
6.2124	6.3418	0.1294
6.2958	6.1617	-0.1341
7.2573	7.3787	0.1214
6.8391	6.9885	0.1494
5.7447	6.0915	0.3468
7.8888	7.9851	0.0963
6.7896	6.6837	-0.1059
6.3762	6.2469	-0.1293

Actual and predicted value of MRR

IV. CONCLUSIONS

The experimental work is performed on EN31 Alloy Steel on WEDM to find the effect of the process parameters viz. Pulse on time (TON), Pulse off time (TOFF), Wire feed (WF), Wire tension (WT) on the MRR. The design for the present work is modeled using Taguchi's methodology and analysis is carried out with the help of Minitab17 software. Finally, the optimum machining combinations of process parameters have been found in the present work to get the best possible response i.e., MRR within the experimental constraints. The following conclusions are made in the present work/.The present work provides a model for four factors (Pulse on time, Pulse off time, Wire feed and Wire tension) with three levels of each parameter on EN31 alloy steel.

- The optimum parameters obtained for Material Removal Rate (MRR) are:
  Pulse on time (Ton)= 126µs, Pulse off time (Toff) = 50 µs, Wire feed = 5 m/min, Wire tension = 8 grams.
- The order strength of parameters found from the response table for MRR is Toff, Ton, Wire feed and Wire tension.
- After carrying out the experiments it is concluded that, for En31 alloy steel the MRR increases with an increase in Pulse on time.

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