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OPTIMIZATION AND COMPARISON OF PROCESS PARAMETERS OF WEDM ON SS316 AND EN31

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ABSTRACT

In the present scenario, there is a high demand of highly precise machined complex and intricate shapes in the manufacturing industry. Wire Electric Discharge Machining (WEDM) is a non- conventional machining process which can generate highly precise machined parts. There are number of process parameters which effects the wire electric discharge machining. In this paper we have to take four input parameters which effects the responses parameters. The process parameters are Pulse on Time (Ton), Pulse of Time (Toff), Wire Feed (WF) and Wire Tension (WT). Which effects on Process response that is Material removal rate (MRR). Taguchi's L9 Orthogonal Array is used to optimize the data and caparisons is done on the Response parameter that is Material removal rate. The stainless steel SS316 and EN31 is used as work materials. The experiment is carried out on ELECTRONICA SPRINTCUT WEDM machine using brass wire of 0.25mm diameter and distilled water is taken as the dielectric fluid..

Keywords-. *EDM,Ton, Toff, MRR, Orthogonal array, WEDM, WF, WT..*

Introduction

Wire EDM process is commonly used as a non conventiontional machining processes in current Manufacturing. It involves metal removal by discharging an electrical current from a pulsating DC power supply across a thin inter-electrode gap between the tool and the work piece. It is mostly used for machining hard and difficult to machine materials with very close tolerances.

A continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small tolerance. There is no direct contact between the work piece and the wire, during machining it eliminates the mechanical stresses. The WEDM is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining processes. The wire EDM machining techniques have been continuously evolving in a mere tool and die Substantial increases in productivity is achieved since the machining is untended, allowing operators to do work in other areas. These machines are worked over full nights without any operator. Most workpieces come off the machine as a finished part, without the need for secondary operations. It's a one-step process.

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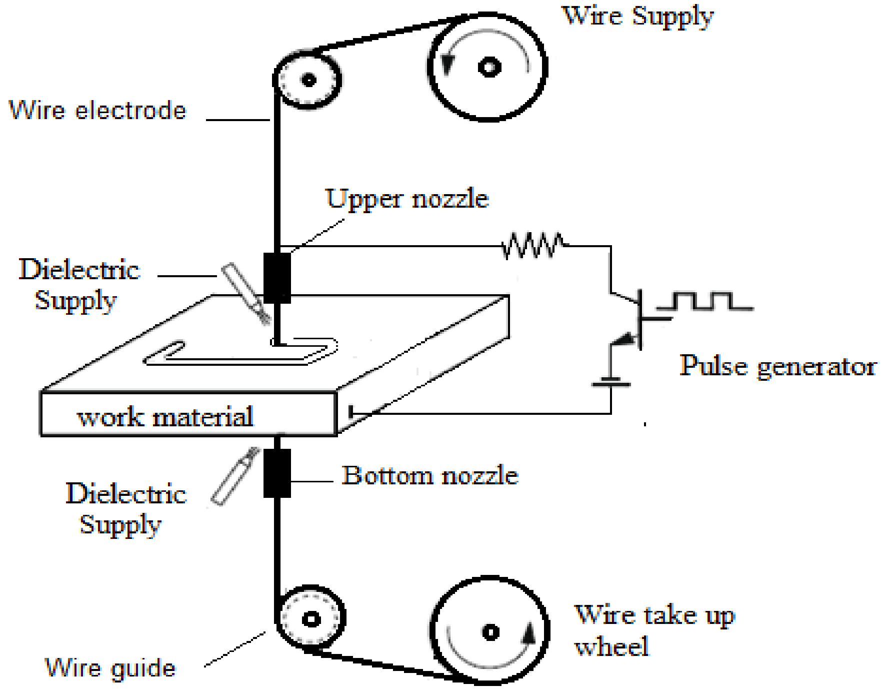

Fig 1.1: Schematic representation of WEDM process

Mechanism of Material Removal Process

In WEDM material is removed by melting by generating an electric spark between the electrodes using a pulsating D.C power supply. The continuously moving wire acts as a cathode while the work piece acts as an anode. The spark is generated in the presence of a dielectric medium. In the present work distilled water is used as a dielectric medium.

When the D.C power supply is switched on, the applied voltage develops an ionized channel between the work piece and the wire electrode. With D.C power supply, current increases and resistance of ionized channel decreases. This increases ionization which in turn generates the magnetic field. The temperature of work material is raised above its melting point due to Compression of ionization channel by magnetic field as kinetic energy of electrons is transformed in to heat. As a result, the metal starts eroding from the surface.

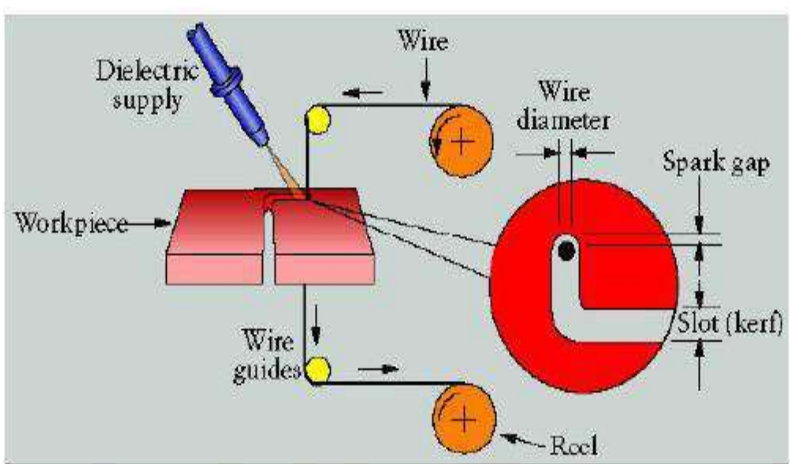

FIG. 1.2 MATERIAL REMOVAL PROCESS

Process (Input) Parameters and Responses in WEDM

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There are many parameters that affect the operations of a WEDM. The parameters which have an impact on the response parameters of WEDM are pulse-on time, pulse-off time, peak current, wire feed, wire tension, polarity, discharge current, pulse wave form, cutting tool and material of work piece. In the present of effect parameters on MRR is to be found. So, the parameters which mainly affect the MRR, are selected after performing pilot experiments. The selected parameters are explained below:-

Process Parameters

Pulse on time (Pulse duration)

It is generally known as pulse on-time or pulse duration. The time interval for which pulses is active, is known as pulse off-time. Pulse on time is the time interval for which current flows into the gap. The unit for pulse on time is microseconds. Pulse on-time is an important parameter because all the work is done during pulse on time. Material removal rate (MRR) depends a lot on the energy applied during the pulse on time. As the pulse duration increases, more heat sinks into the work piece which results in a larger recast layer and a deeper heat-affected zone. Material removal rate starts decreasing after an optimal value of pulse duration.

Pulse off time

Pulse off time may be defined as the pause between the discharges that allows the debris to solidify and the flush away by the dielectric fluid before the next discharge. A decrease in the pulse off time increases material removal by allowing more discharge per unit time. Although, decreasing pulse off time below a particular value may also result in overloading of the wire, which may break the wire and may cause instability of cut by not giving enough time to take away the debris by dielectric fluid before the next change. The pulse off time mainly affects material removal rate and the stability of cut. As the pulse off time decreases, the machining operation becomes fast.

Wire feed

Wire feed is the speed at which the wire-electrode is fed along the wire guide path for sparking.

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 to keep the continuously fed wire under tension due to which the wire remains straight between the wire guides.

Process Responses:

Material Removal Rate

The rate of removing the material from the work piece is called Material Removal Rate. In WEDM material is removed by melting by generating electric sparks between the wire electrode and the work piece immersed in a dielectric fluid (distilled water in the present work) using a pulsating D.C power supply. The electrical sparks melt and vaporize small amount of the work piece material, which is then ejected and taken away by the dielectric fluid.

MRR value is obtained by the following equation:

$MRR = (Wb–Wa)/(Tm\times\rho)(mm3/sec)$

Where Wb is weight before machining,

Wa is weight after machining,

Tm is machining time and

ρ is the density of work piece in g/mm3.

LITERATURE REVIEW

Han et al. (1) conducted experiments on WEDM EU64 to machine alloy steel (Crl2) having thickness of 40 mm. It was reported that the surface finish improved by decreasing pulse duration and discharge current. Gauri and chakraborty (2) suggested a modified approach of the principal component analysis (PCA) based procedure for multi-response optimization. Analysis was done on experimental data on WEDM processes obtained by the past researchers i.g. on ɤ- titanium aluminized alloy with the settings of six controllable factors. Quality characteristics were material removal rate (MRR) (larger the better type), surface roughness (SR)(smaller the better type) and wire wear ratio (WWR)(smaller the better type). The result included that the optimal conditions derived based on the WPC method can offer significant improvement in overall quality level. Rao and sarcar (3) studied the effects of process parameters on machining characteristics for CNC WEDM bor brass work pieces of varying thickness. Mathematical relations were obtained for cutting speed, spark gap and MRR. Manna and kumar (4) investigated the effects of various cutting parameters of WEDM on wire crater depth, electrode wear rate and surface roughness using Taguchi methods based on L-18 mixed orthogonal array. Parshar et al. (5) prepared a design of experiments by using Taguchi approach for the optimization of surface roughness. They provided the suitable parametric condition for special case of steel which have been selected as a work piece material. Singh and Garg (6) investigated the effects of process parameters on material removal rate of WEDM. It was found that Material Removal Rate directly increases with increase with pulse on time and peak current while pulse off time and servo voltage decreases. Kamal jangra (7) studied optimization of performance characteristics in WEDM using Taguchi method and Grey Relation Analysis. Performance characteristics (cutting speed, surface roughness) were investigated during rough cutting operation. Process parameters (peak current, pulse on, pulse off) were investigated using mixed L18 orthogonal array. It was concluded that, cutting speed (3.80mm/min.) can be achieved with a dimensional lag of 0.008mm. Md. Ashikur Rahman Khan et. al (8) established a model which can accurately predict the material removal rate (MRR) of titanium alloy by correlating the process parameter. Effect of the parameter on MRR is investigated as well. Experiment is conducted utilizing the graphite electrode maintaining negative polarity. Analysis and modeling is carried out based on design of experiment as well as response surface methodology. The agreeable accuracy is obtained. The confirmation test reveals the error from 1.82% to 9.19 with a mean error as 4.29%which is acceptable as less than 10%. Kamal janra et al. (9) studied the wire electric discharge machining of WC-CO composite. Influence of taper angle, peak current, pulse-on time, pulse-off time,wire tension and dielectric flow rate are investigated for MRR and SR during intricate machining of carbide block. In order to optimize MRR and SR simultaneously, grey relational analysis (GRA) is employed along with Taguchi method. The optimal combination of the process parameters, using GRA for multi-machining characteristics is set to taper angle1 (30), B3 (120 ampere), pulse on time(108 µs), pulse of time(40µs). Anish kumaret al. (10) presented an investigation on WEDM of pure titanium (grade-2). An attempt has been made to model the response variable i.g. surface roughness in WEDM process using response surface methodology. The experimental plan is based on Box-Behnken design. Six parameters i.g. pulse on time, pulse off time, peak current, spark gap voltage,wire feed and wire tension has been varied to investigate their effect on surface roughness. In this work, it was concluded that the surface roughness was ranged from 2.48µm to 2.62µm during WEDM of pure titanium. Manoj Malik et al.(11) applied gray based Taguchi technique to get optimized input parameters for wire EDM and suggested that pulse on time is most affecting input parameter for surface roughness and duty factor is least significant parameter. Denial Ghodsiyeh et al. (12) experimentally studied that the design of experiment (DOE) method for selection of optimal cutting parameters during WEDM of titanium alloy (Ti6Al4V). Moreover, the behavior of three control parameters such as pulse ON time (A), pulse OFF time (B) and peak current (C) on machining performance , including MRR and SR is studied using analysis of variance (ANOVA). It was concluded that, several optimal conditions can be gotten from analysis, including the multi-objectives condition can be set by pulse on time : 10µs, pulse off time: 6.5µs,peak current: 33A. The predicted result as MRR 0.3913 mm3/sec surface roughness: 3.122µm. Jaganathan et al. (13) investigated the effects of different input parameters on material removal rate and surface roughness and got the result using Taguchi optimization technique that voltage, pulse width, and wire speed is critical input parameters.Sorabh et al. (14) Studied that surface finish can be improved by decreasing both pulse duration and discharge current. This indicates short pulse durations. S.B.Prajapati and Patel (15) Suggested that pulse on time and pulse off time effected cutting rate and surface roughness critically machining process parameters on AISI A2 tool steel in wire electric discharge machining. Lokeswara Rao T. and N. Selvaraj (16) presented optimum cutting parameters for titanium grade 5 (Ti-6AI-4V) using wire-cut electrical machining process (WEDM). The response of volume material removal rate (MRR) and surface roughness (Ra) are considered for improving the machining efficiency. In the experiments, a brass wire of 0.25mm diameter was applied as tool electrode to cut the specimen. The experimentation has been done by using Taguchi L25 orthogonal array (OA) under different conditions like pulse on, pulse off, peak current, wire tension, servo voltage and servo feed settings. In this work, Taguchi analysis determines the factors which have significant effect on volume material removal rate. Equations which correlate machining parameters with material removal rate is found by regression analysis, and the optimal setting is found by S/N ratio analysis.

TAGUCHI'S EXPERIMENTAL DESIGN METHODOLOGY

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Taguchi recommends orthogonal array (OA) for carrying out experiments. These OA"s are generalized Graeco-Latin squares. To design an experiment is to select the most suitable OA and to assign the parameters and interactions of interest to the appropriate columns. The use of linear graphs and triangular tables suggested by Taguchi makes the assignment of parameters simple. The array forces all experimenters to design almost identical experiments (Roy, 1990).

In the Taguchi method the results of the experiments are analyzed to achieve one or more of the following objectives (Ross, 1988):

- To establish the best or the optimum condition for a product or process
- To estimate the contribution of individual parameters and interactions
- To estimate the response under the optimum condition

In the present work Taguchi's L9 orthogonal array has been used with ANOVA for finding the optimum results.

EXPERIMENTAL SETUP AND MEASUREMENTS

Machine Tool

The experiments were carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT734) of Electronica Machine Tools Ltd.

Figure 4.1 (ELEKTRA SPRINTCUT 734) of Electronica Machine Tool

Work piece material:

The work piece material used for study is stainless steel 316 and Alloy Steel. The stainless steel 316 has been used as a workpiece Having high tensile strength, shock resistance and better ductility and high hardeness at elevated temperature. It is most common grade of stainless steels. EN 31 is a high Carbon alloy steel having high hardness with high compressive strength and abrasion resistance. EN is designated as per European Standard for series of such high carbon steel alloy like EN 8, EN19, EN24, EN31 etc

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 is shown in Figure 4.2. A set of specimens cut from the blank is shown in Figure 4.3.

Fig 4.2 EN31 Work Material mounted

Fig 4.3 SS316 Work Material mounted

RESULTS AND DISCUSSION

The results of the present work obtained are analysed using S/N ratios, response tables and graphs are obtained with the help of Minitab software.

Table -1 represents the L_9 orthogonal array

S.No.	T_{on} (μs)	T_{off} (μs)	WF (m/min)	WT (gms)	MRR SS316 (mm^3/sec.)	MRR EN31 (mm^3/sec.)
1	115	55	4	7	0.8816	5.9947
2	115	57	5	9	1.8092	6.3418
3	115	59	6	11	1.3728	6.1617
4	116	55	5	11	1.7690	7.3787
5	116	57	6	7	1.7783	6.9885
6	116	59	4	9	1.7310	6.0915
7	117	55	6	9	1.8667	7.9851
8	117	57	4	11	2.0637	6.6837

9	117	59	5	7	1.9580	6.2469

Larger is better

Table-2 Response table for S/N ratios for MRR of SS316

Level	T_{on}	T_{off}	Wire feed	Wire tension
1	2.284	3.140	3.336	3.262
2	4.907	5.481	5.314	5.144
3	5.882	4.451	4.423	4.667
Delta	3.598	2.341	1.978	1.882
Rank	1	2	3	4

Table-3 Response table for means for MRR of SS316

Level	T_{on}	T_{off}	Wire feed	Wire tension
1	1.356	1.514	1.560	1.541
2	1.759	1.884	1.845	1.809
3	1.970	1.687	1.679	1.735
Delta	0.614	0.370	0.285	0.268
Rank	1	2	3	4

Larger is better

Table-4 Response table for S/N ratios for MRR of EN31

Level	T_{on}	T_{off}	Wire feed	Wire tension
1	15.80	16.99	15.92	16.12
2	16.65	16.48	16.44	16.59
3	16.82	15.80	16.91	16.55
Delta	1.02	1.19	0.99	0.48
Rank	2	1	3	4

Table-5 Response table for means for MRR of EN31

Level	T_{on}	T_{off}	Wire feed	Wire tension
1	6.166	7.119	6.257	6.410
2	6.820	6.671	6.656	6.804
3	6.972	6.167	7.045	6.741
Delta	0.806	0.953	0.788	0.396
Rank	2	1	3	4

s

Figure-5.1 Response graphs for means for MRR of SS316

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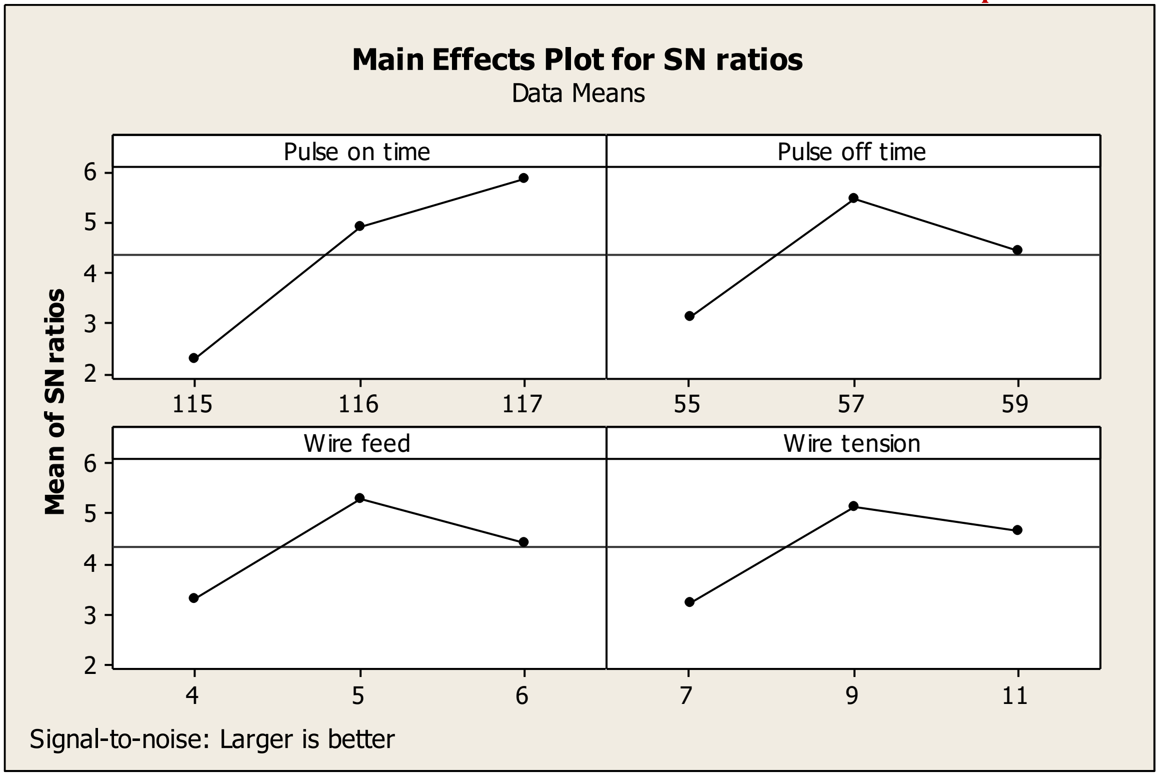

Figure-5.2Response graphs for means for MRR of SS316

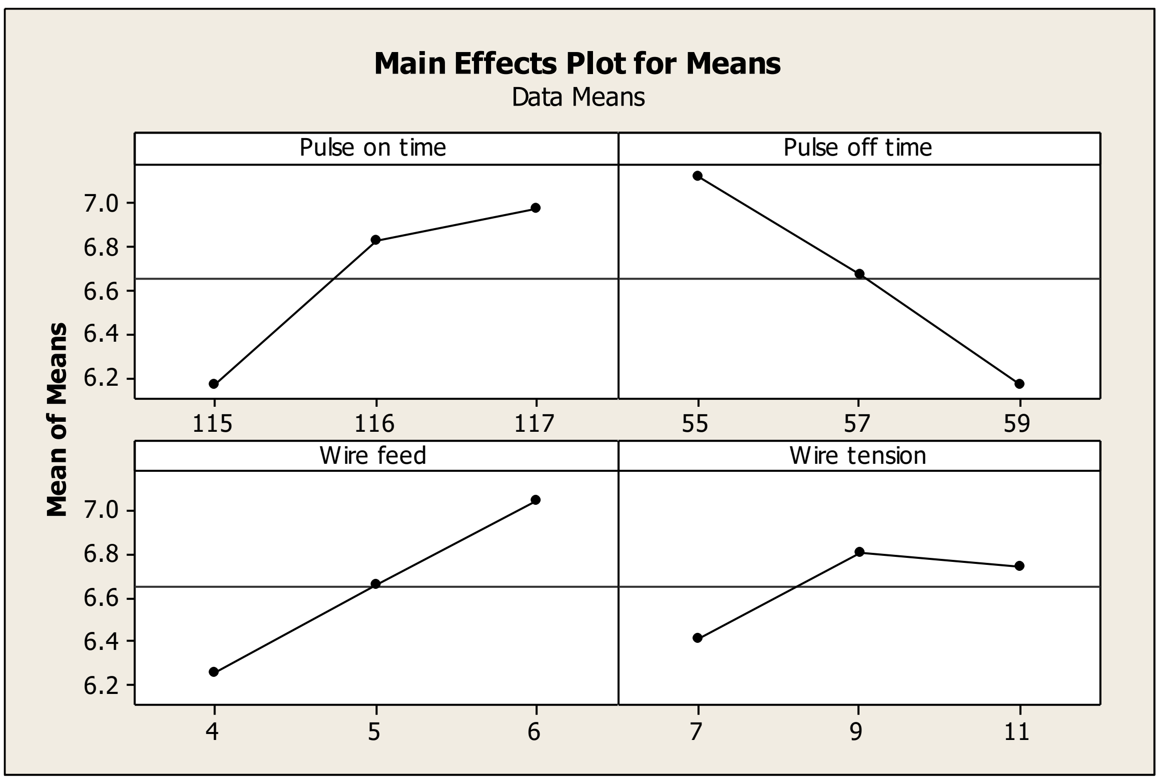

Figure-5.3 Response graphs for means for MRR of EN31

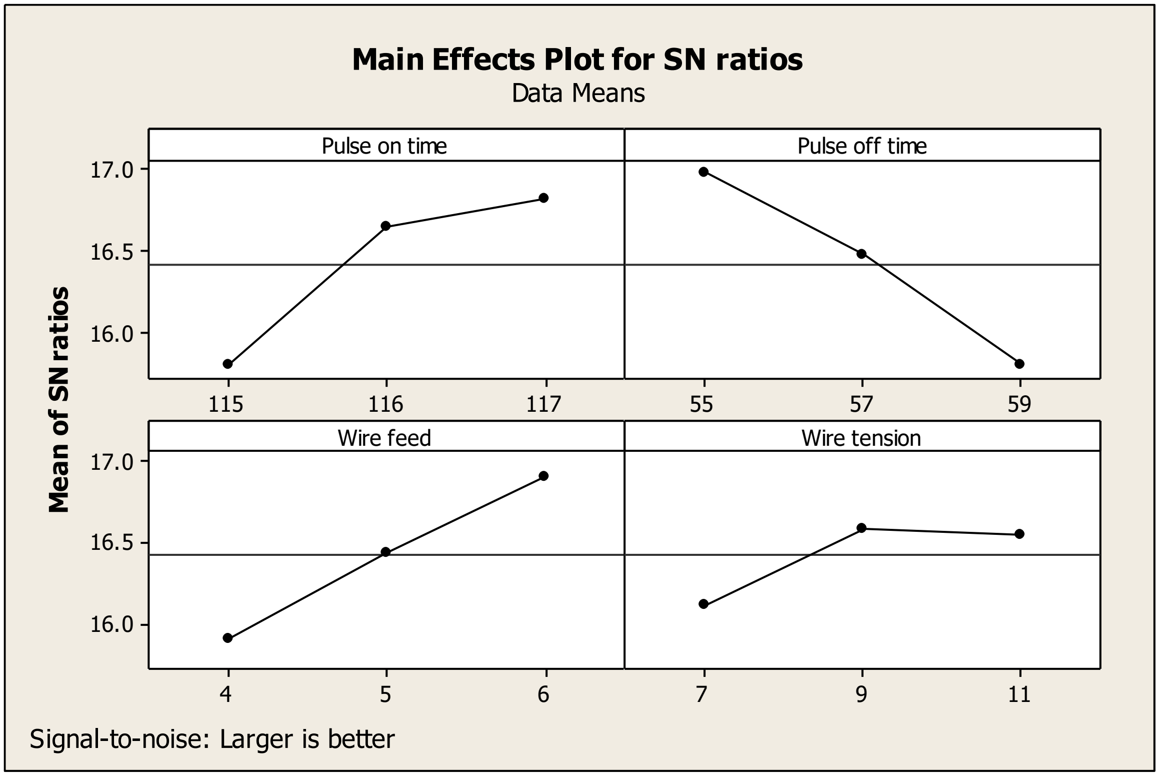

Figure-5.4 Response graphs for means for MRR of EN31

Table 6 Optimal level for MRR of SS316

	Pulse on time	Pulse off time	Wire feed	Wire tension
Optimal level	117	57	5	9

Table 7 Optimal level for MRR of EN31

	Pulse on time	Pulse off time	Wire feed	Wire tension
Optimal level	117	55	6	9

CONCLUSIONS

The experimental work is performed on SS316 and 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 SS316 and EN31 alloy steel.

After studying the results and discussions the following conclusions made regarding the present work.

1. The optimum parameter setting is Pulse on time- 117 µs, Pulse off time-57 µs, Wire feed-5m/min and Wire Tension-9 m/min for maximum MRR of SS316.
2. The optimum parameter setting is Pulse on time- 117 µs, Pulse off time-55 µs, Wire feed-6m/min and Wire Tension-9 m/min for maximum MRR of SS316.

3. The order strength parameters are found from response table for MRR on SS316 is Ton, $Toff_f$, Wire feed and Wire tension.
4. The order strength of parameters found from the response table for MRR on EN31 is Toff, Ton, Wire feed and Wire tension.
5. The MRR For EN31 is more than SS316.

FUTURE SCOPE

1. The present work is made on the SS 316 and EN31. So the procedure can be employed for the other grades of stainless steels and alloy steels.
2. The work also can be performed by changing the process parameters and process responses.
3. The work also can be done with the use of different techniques like RSM, GRA and other techniques.

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