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Effects of Process Parameters on Performance Measure of WEDM on SS316

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Abstract: As the demands of highly precise machined complex and intricate shapes geometries are increasing in present days manufacturing, so that the conventional machining processes are replaced by non-conventional machining processes like WEDM. By which the more precise intricate shapes are easily machined. In the present paper the study has been made to optimize the process parameters during machining of SS316 by WEDM using Taguchi's technique. The four process parameters for WEDM namely Ton, Toff, WF, WT are chosen as variable to study the process performance in terns of MRR and Ra. Based on the chosen process parameters and performance measure taguchi's L9 orthogonal array is selected to optimize the best suited values for cutting SS316 by WEDM process. The experimental study are performed on ELECTRONICA SPRINTCUT WEDM machine. In present study brass wire of 0.25mm diameter used as atool and distilled water is used as dielectric fluid.

Keywords: WEDM; Ton; Toff; WF; WT; MRR; Ra.

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1. INTRODUCTION

WEDM process is one of the most widely used non- traditional machining processes in current manufacturing. It involves the removal of metal 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 most commonly used for machining hard and difficult to machine materials with very close tolerances. Generally, WEDM is perceived to be an extremely actuate process and there are various reasons for this perception. It can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminum, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the work piece, so there is no physical pressure imparted on the work piece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the work piece.

Wire EDM also gives designers more latitude in designing dies, and management more control of manufacturing, since the machining is completed automatically. Parts that have complex geometry and tolerances don't require you to rely on different skill levels or multiple equipment. Substantial increases in productivity is achieved since the machining is untended, allowing operators to do work in other areas. Most machines run overnight in a "lights-out" environment. Long jobs are cut overnight, or over the weekend, while shorter jobs are scheduled during the day. Most work pieces come off the machine as a finished part, without the need for secondary operations. It's a one-step process.

2. LITERATURE REVIEW

Williams and rajurkar (1)performed experimental investigations on WEDM to study the wire electrical discharged machined surface characteristics. The objective of research was to stochastically model and analyze WEDM surface profiles to gain a better understanding of the surface generating mechanism. Further scanning electron microscopy and energy dispersive spectrometry were also used to study WEDM surface characteristics. Lin and Lin (2)reported a new approach for the optimization of the electrical discharge machining (EDM) process with multiple performance characteristics based on the orthogonal array with the grey relational analysis. Optical machining parameters were determined by the grey relational grade obtain from the grey relational analysis as the performance index. The machining parameters, namely work piece, polarity, pulse on time, duty factor, open discharge voltage, discharge current and dielectric fluid were optimized with considerations of multiple performance characteristics including material removal rate, surface roughness, and electrode wear ratio. Puri and Bhattachryya (3) employed Taguchi methodology involving thirteen control factors with three levels for an orthogonal array L27 to find out the main parameters that affects the different machining criteria, such as average cutting speed, surface roughness values and the geometrical inaccuracy caused due to wire lag. Huang and Liao (4)presented the use of grey relational and S/N ratio analysis, for determining the optimal parameters setting of WEDM process. The results showed that the MRR and surface roughness are easily influenced by the table feed rate and pulse on time. Kuriakose et al .(5)carried out experiments with titanium alloy (Ti-6Al-4V) and used a data- mining technique to study the effect of various input parameters of WEDM process on the cutting speed and SR. They reformulated the WEDM domain as a classification problem to identify the important decision parameters. In their approach, however, the optimal process parameters for the multiple responses need to be decided by the engineers based on judgment. Yan et al. (6)performed experiments on FANUC WI CNC wire electrical discharge machine for cutting both the 10 and 20 vol. % AL203 particles reinforced 6061 Al alloys-based composite and 6061 Al matrix material itself.

Results indicated that the cutting speed (material removal rate), the surface roughness and the width of the slit of cutting test material significantly depend on volume fraction of reinforcement (Al203 particles). Sarkar et al. (7)perform experimental study using ɤ-titanium aluminide alloy as work material and then formulation of mathematical models to predict the cutting speed, surface finish and dimensional deviation as the function of different control parameters. They determined the optimal process parameters by applying constrained optimization technique in which one performance characteristics was optimized considering other as constraints. Kuriakose and shunmugam (8)used titanium alloy (Ti-6Al-4V) as the work material and conducted experiments based on taguchi"s L-18 orthogonal array. Then they employed the non-dominated sorting genetic algorithm to determine the optimal process parameters that would optimize cutting velocity and SR of WEDM process. Ramakrishnan and karunamoorthy (9)performed the multi objective optimization of the WEDM process using parametric design of Taguchi methodology.

The effect of various machining parameters such as pulse on time, wire feed speed, wire tension, delay time, and ignition current intensity has been studied in machining of heat-treated tool steel. It was identify that the pulse on time and ignition current intensity has influence more than the other parameters. Moreover, the multiple performance characteristics such as material removal rate, surface roughness, and wire wear ratio for the WEDM process could be improved by setting the various process parameters at their various levels. Chiang and chang (10)presented an approach for the optimization of the WEDM process of Al2O3 particle reinforced material with two performance characteristics, e.g. SR and MRR, based on the grey relational analysis. Mahapatra and patnaik (11) conducted experiments on ROBOFIL 100 high precision 5 axis CNC WEDM to find the relationship between controls factors and responses like MRR, SF and kerf by means of non-linear regression analysis. Genetic algorithm was employed to optimize the WEDM process with multiple objectives.

The error associated with MRR, SF, and kerf were 3.14%, 1.95%, and 3.72%, respectively. The optimum search of machining parameter values for maximizing MRR and SF and minimizing kerf was formulated as a multi-objective, multivariable, nonlinear optimization problem. Kanlayasiri and Boonmung (12)investigated influences of wire-EDM machining variables of surface roughness of newly developed DC 53 die steel of width, length, and thickness 27, 65, and 13 mm, respectively. The machining variables included pulse-on time, pulse-off time, pulse-peak current, and wire tension. The variables influences the surface roughness were identified using ANOVA technique. Results showed that pulse-on time and pulse-peak current were significant variables to the surface roughness of wire-EDM DC 53 die steel. The maximum prediction error of the model was less than 7% and the average percentage error of prediction was less than 3%.Han et al. (13) 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.

3. EXPERIMENTAL SET UP

3.1 Selection of work piece

The work piece material used for study is stainless steel 316. The stainless steel 316 plate of size 243mm×75mm×4mm has been used as a work piece Having high tensile strength, shock resistance and better ductility and high hardness at elevated temperature. It is most popular of stainless steels. The chemical composition of stainless steel 316 work piece is given below in table

Table 1: Chemical composition of Work piece

Constituent	% Composition
Carbon	0.08 max.
Manganese	2 max.
Phosphorus	0.045max.
Sulfur	0.03 max.
Silicon	1 max.
Chromium	16-18
Nickel	10-14
Molybdenum	2-3

3.2 Electrode Material

In the present work Brass wire of diameter 0.25 is consider as the electrode material.

3.3 Design of experiment

The design of experiments technique is a very powerful tool, which permits to carry out the modeling and analysis of the influence of process variables on the response variables. The response variable is an unknown function of the process variables, which are known as design factors. The purpose of running experiments is to characterize unknown relations and dependencies that exist in the observed design or process, i.e. to find out the influential design variables and the response to variations in the design variable values. A scientific approach to planning the experiment must be employed if an experiment is to be performed most efficiently. So in present work there are four input parameters are selected Pulse on time(T_{on}), Pulse off time(T_{off}), wire feed(WF) and wire tension (WT).).the effects of these parameters are examined on Material removal rate(MRR) and surface roughness(Ra).and make L_9 orthogonal array to analysis of taguchi;s optimization technique.

Table 2: shows the input variable parameters

Machining parameters	Levels		
	Level 1	Level 2	Level 3
Pulse on time	115	116	117
Pulse off time	55	57	59
Wire feed	4	5	6
Wire tension	7	9	11

L_9Orthogonal array

Table 3: Experimental plan with assigned values

S.No.	T_{on} (µm)	T_{off} (µm)	WF (m/min)	WT (gms)
1	115	55	4	7
2	115	57	5	9
3	115	59	6	11
4	116	55	5	11
5	116	57	6	7
6	116	59	4	9
7	117	55	6	9
8	117	57	4	11
9	117	59	5	7

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Table 4: shows the fixed parameters

Work material	SS316
Tool material	Brass wire of diameter 0.25
Flushing pressure	1 unit
Work piece height	4mm
Servo feed	2150

4. Experimental work

The experiment is conducted on Electronica Sprintcut wire electric discharge machine. All the axes and servo voltage is controlled in this machine is by CNC codes which is coded in the control pannel. All type of profile which has been cut is designed by CAD software in the computer system. The machine can be programmed through CNC codes. The small gap is maintained between the tool i.e brass wire and work piece i.e stainless steel plate near about 0.020mm. the high energy generated is eroded the material from the stainless steel plate which is work material by melting. The distilled water is used as dielectric fluid which is fixed as 1 unit. This flushing water is collected after eroding material in the collection tank. The tool that is brass wire having diameter 0.25mm cannot be used twice. It is used only a time due to inaccuracy in dimension. The experiments were carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT 734) of Electronica Machine Tools Ltd.

Figure 2 : (ELEKTRA SPRINTCUT 734) of Electronica Machine Tools Ltd.

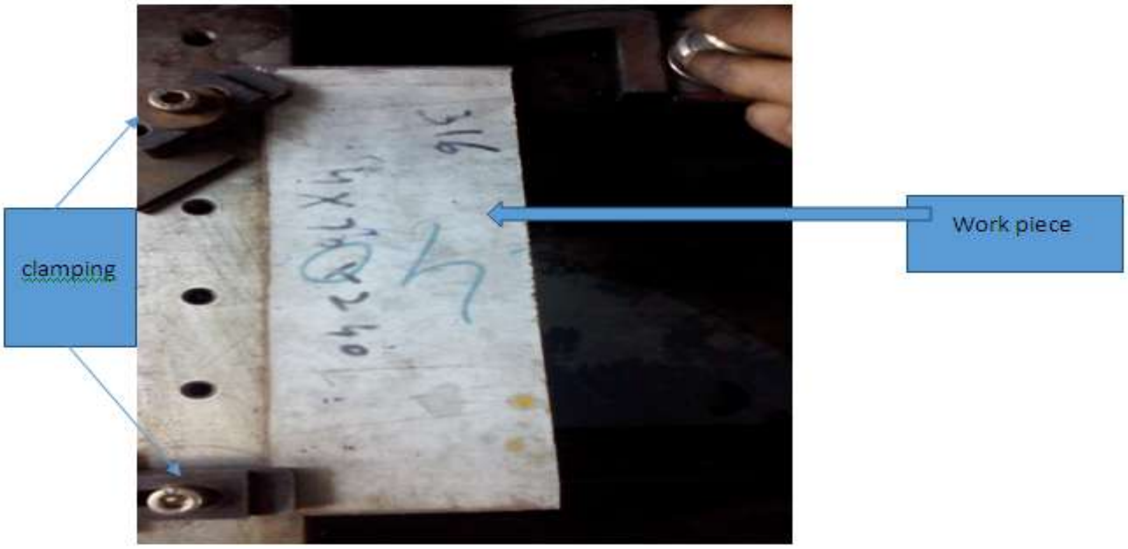

Figure 3: clamped work piece on work head

Process responses

Material removal rate (MRR)

Material removal rate is find out in the present work is by a mathematical relation

MRR= $(W_b - W_a) / (T \times p)$ (mm3/sec)

Where W_b is weight before machining

W_a is weight after machining

T is machining time

p is density of the material

Surface roughness (Ra)

The surface roughness was measured by Mitutoyo surftest SJ-210. Before taking measurement of surface roughness, the work piece was cleaned with acetone. The surftest is a shop-floor type surface-roughness measuring instrument, which traces the surface of various machine parts and calculates the surface roughness based on roughness standards, and displays the results in µm.

5. 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 -5: represents the L_9 orthogonal array

S.No.	T_{on} (µm)	T_{off} (µm)	WF (m/min)	WT (gms)	MRR (mm^3/sec.)	Ra (µs)
1	115	55	4	7	0.8816	3.54
2	115	57	5	9	1.8092	3.58
3	115	59	6	11	1.3728	3.76
4	116	55	5	11	1.7690	3.60
5	116	57	6	7	1.7783	3.76
6	116	59	4	9	1.7310	3.96
7	117	55	6	9	1.8667	3.66
8	117	57	4	11	2.0637	4.14
9	117	59	5	7	1.9580	3.74

4.1 Selection of best parameters

Parameters are selected on the basis of Taguchi;s analysis.MRR and Ra versus T_{on}, T_{off}, wire feed and wire tension is carried out and average of each level is the parameter for raw data is given in below tables.

Table-6: Response table for S/N ratios for MRR

Larger is better

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-7 Response table for means for MRR

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

Table-8 Response table for S/N ratios for Surface Roughness

Smaller is better

Level	T_{on}	T_{off}	Wire feed	Wire tension
1	-10.95	-11.13	-11.76	-11.31
2	-11.52	-11.40	-10.98	-11.20
3	-11.69	-11.64	-1142	-11.66
Delta	0.74	0.51	0.77	0.46
Rank	2	3	1	4

Table-9 Response table for means for Surface roughness

Level	T_{on}	T_{off}	Wire feed	Wire tension
1	3.533	3.600	3.880	3.677
2	3.770	3.730	3.547	3.640
3	3.847	3.820	3.723	3.833
Delta	0.313	0.220	0.333	0.193
Rank	2	3	1	4

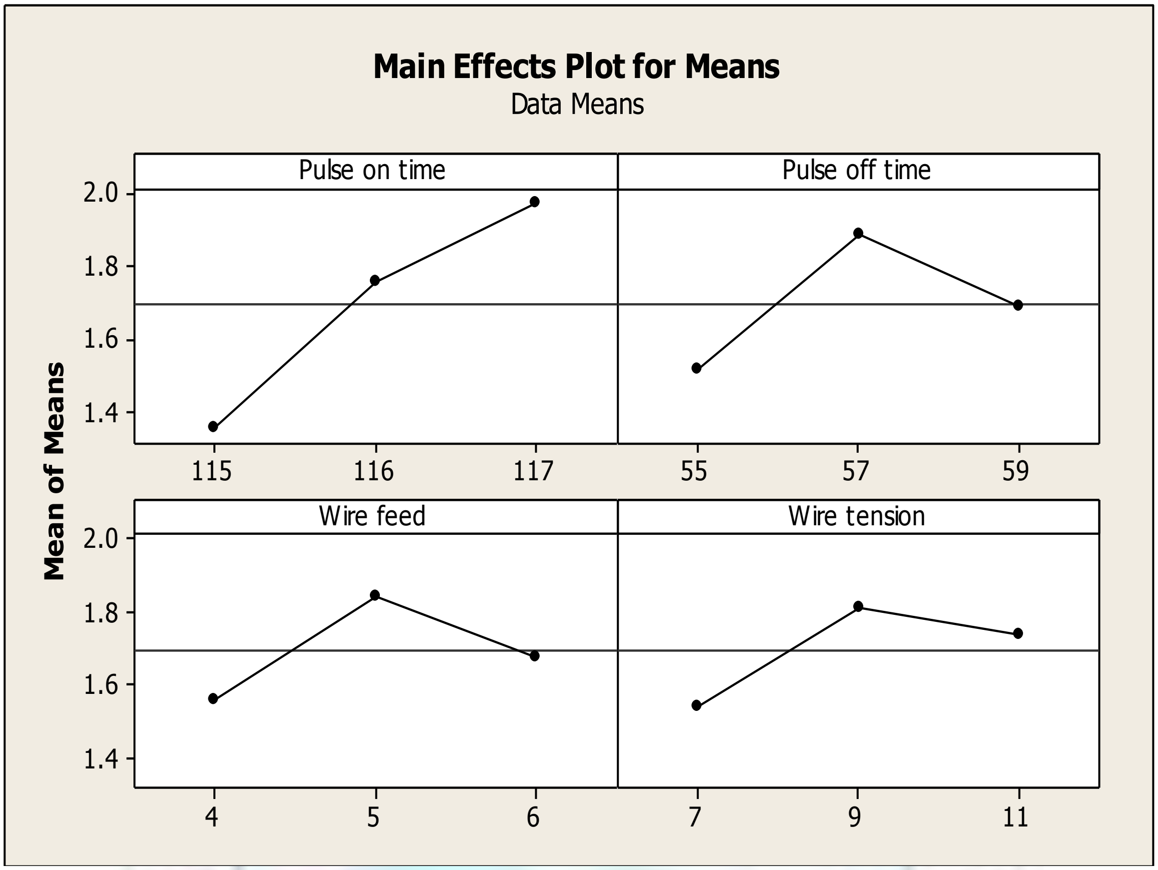

Figure-4 Response graphs for means for MRR

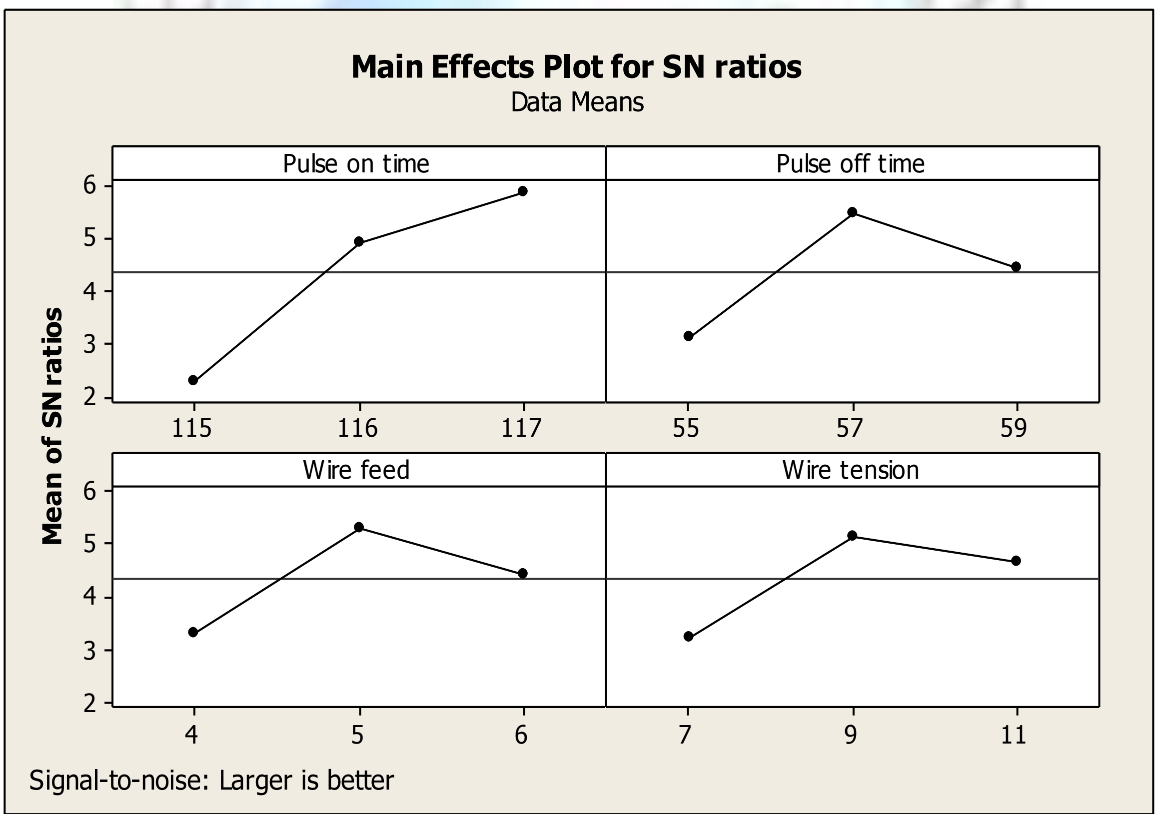

Figure-5 Response graph for S/N ratio for MRR

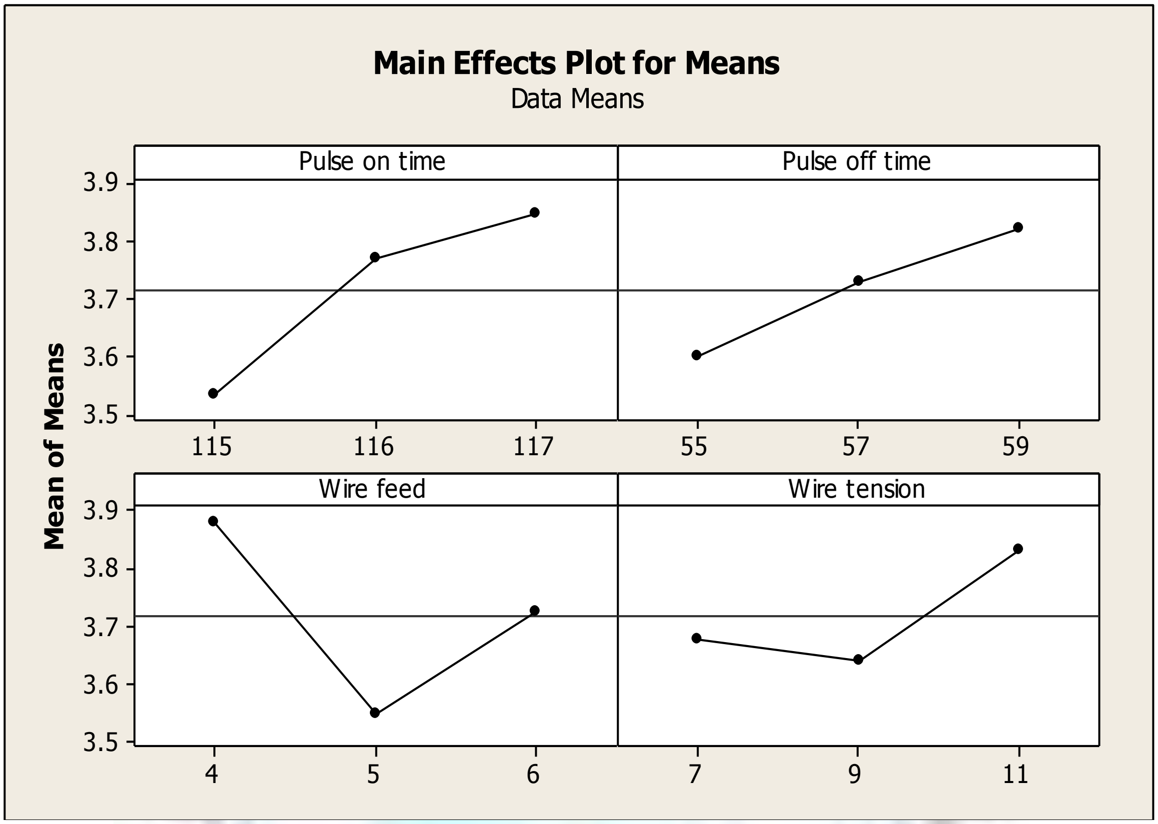

Figure-6 Response graph for means of Ra

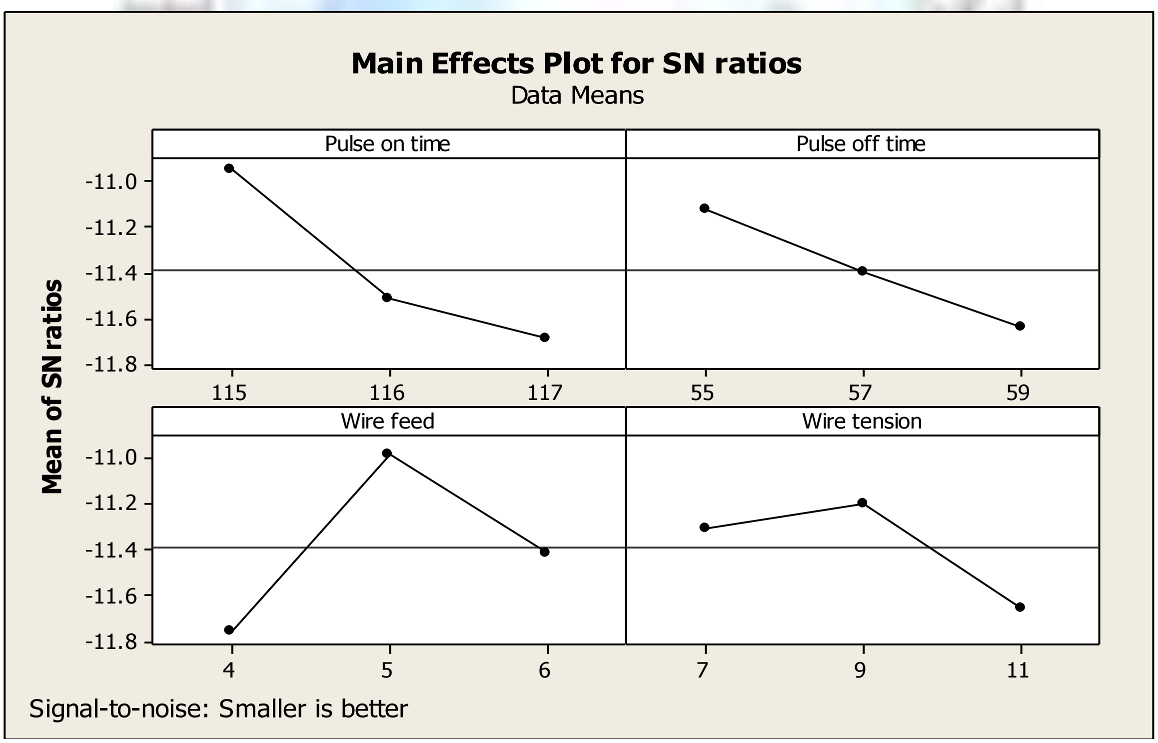

Figure 7 Response graph for S/N Ratio of Ra

4.2 Development of Regression equation

The aim of multiple regression analysis is to construct a model that explains as much as possible, the variability in a dependent variable, using several independent variables.
The regression equation for MRR is given by
The regression equation is
MRR = - 37.1 + 0.307 Pulse on time + 0.0433 Pulse off time + 0.060 Wire feed + 0.0486 Wire tension
The regression equation for Ra is given by

The regression equation is
Ra = - 17.6 + 0.157 Pulse on time + 0.0550 Pulse off time - 0.0783 Wire feed + 0.0392 Wire tension
With the help of Regression equations the predicted values of MRR and Ra is estimated and their deviation is tabulated. It is observed that the predicted values are closer to experimental values as in Table-9 &10.

Table-9 Actual and Predicted value of MRR

Predicted MRR	Actual MRR	Deviation
0.86052	0.8816	0.8589
1.4105	1.8092	-0.3987
1.6543	1.3728	0.2815
1.7281	1.790	-0.0409
1.6803	1.7783	-0.0980
1.7441	1.7310	0.0241
1.9979	1.8667	0.1312
2.0617	2.0637	-0.0020
2.0139	1.9580	0.0559

Table-10 Actual and Predicted value of Ra

Predicted Ra	Actual Ra	Deviation
3.4412	3.54	-0.0988
3.5513	3.58	-0.0287
3.6614	3.75	-0.0886
3.6767	3.60	0.0757
3.5516	3.76	-0.2084
3.8966	3.96	-0.0634
3.6770	3.66	0.017
4.0220	4.14	-0.118
3.8969	3.74	0.1569

Conclusions

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

1. The better parameter setting is Pulse on time- 117 µs, Pulse off time-57 µs, Wire feed-4m/min and Wire Tension-11 m/min for maximum MRR.
2. The better parameter setting for minimum Surface Roughness is Pulse on time-115µs, Pulse off time-55µs, wire feed-5m/min and Wire tension-7 gms.
3. The order strength parameters are found from response table for MRR is T_{on}, T_{off}, Wire feed and Wire tension.
4. The order strength parameters are found from response table Surface Roughness isT_{off} , Wire feed, T_{on},Wire tension.
5. After performing the experiments it is concluded that with the increase in Pulse on time and Pulse off time the MRR in the present work increase and with the increase of WF and WT the MRR decreases for 316.

Future Scope

1. The present work is made on the SS 316. So the procedure can be employed for the other grades of stainless steels and composites.
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 techniues.

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