Experimentation On Powers Over The Operating Factors On Surface Quality In WEDM Of 12X18H10T - Stainless Steel

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Abstract-
The demand for high surface finish in hard to cut materials with complex profiles are recently increasing by increase of design modifications, new product geometries, etc. Wire cut Electrical Discharge Machining is kind of unconventional machining process generally employed for meeting such requirements. The materials which withstand its mechanical properties even it exposed to extremely high temperature are preferred for aerospace. An austenitic alloy 12X18H10T - Stainless Steel is such kind of material which utilized in aerospace at elevated temperature. This study aims to examine maximize surface quality of WEDM of 12X18H10T - Stainless Steel and establish a mathematical model to predict the response in by means of input parameters. This investigation utilized the Taguchi L9 experiential Design with factors of Pulse off Time, Wire Tension, Pulse on Time, and Wire Feed Rate. A constant machining time the effects of above four parameters on surface quality was investigated and optimized parameters for best surface quality.

Key Words: Pulse on Time, 12X18H10T - Stainless Steel, Surface Quality, Taguchi Method, Wire Feed Rate, Wire Tension, Pulse off Time, WEDM,

1. INTRODUCTION

The research on machining of toughest materials is widely popular. The study also the motivation on machining of material which demands high precision on finish and where their precision causes a serious issue is focused. Super alloys are one of such kind of materials which needs high accuracy. Because their applications are; high speed gas turbines and aerospace components [1]. The complex contours like bio implants are difficult machine in the conventional machining practices [2]. Not only the component profile but also the material toughness and its hardness, strength to with stand with its inherent mechanical properties also one of the reason to study the machining parameters optimization in the unconventional machining like WEDM [3] e.g., components of aerospace engine, guide vanes and blades of the gas turbine rotors, turbocharger impellers etc [4]. The nickel based cast alloy of IN713 Cisa γ′ precipitation hardened can withstand up to 800 °C with excellent mechanical properties. Its physical properties are helps to cast it well [5,6]. Though it has wide application, it is mainly preferred for components of Turbochargers which operates at 1, 50,000 rpm at 760 °C [7]. The influence of nano-powder mix in the electrolyte in surface quality was studied by [8,9]. [10] investigated and reported the feasibility of machining of 12X18H10T - Stainless Steel in Electrical Discharge Machining. This study investigates with the aim of optimizing process parameters of wire cut EDM to maximize the surface quality.

2. MATERIALS AND METHODS

This investigation is to optimize the influencing parameters for the most wanted response of surface quality which measure in terms of surface roughness in WEDM of 12X18H10T - Stainless Steel. Even though some studies reported in the literature this study is unique by work material focus for aero space application which is employed in elevated temperature.

2.1 Work material:

12X18H10T - Stainless Steel has wide application in the aerospace and it is a type of Stainless Steel which exhibits its excellent mechanical properties even at elevated temperature from 800 ^{o}F to 1500^{o}F .its constituents are presented in the table 1. Its unique properties are stratural integrity, stability of mechanical properties at elevated temperatures, high Creep strength, excellent machine-ability, and appreciable stress rapture resistant. It is utilized for high temperature jet engine components, exhaust ducts, exhaust manifold of piston engine, and flanges.

Table 1 Composition of 12X18H10T - Stainless Steel

Descript ion of Material Compos ition	Silico n	Chro mium	Sulphur	Manga nesh	Phosph orous	Titaniu m	Nickel	Carbon	Tungst en	Molyb denum
Chemica l Formula	Si	Cr	S	Mn	P	Ti	Ni	C	W	Mo
% of Compos ition	0.800	18.00 0	≤0.020 0	1.500	≤ 0.035	0.700	10.00 0	0.120	≤ 0.200	≤ 0.500

2.2 Experimental Facility

Figure 1 demonstrates the working of WEDM. It is obvious that even tensions on the wire ($\boldsymbol{W_T}$), its feed rate ($\boldsymbol{W_F}$) also influence along with the electrical parameters like On ($\boldsymbol{P_{ON}}$) and Off ($\boldsymbol{P_{OFF}}$) times of Pulse on the surface quality using the multiple regression method for modeling and optimize the process parameters with help of sorted genetic algorithm to achieve the best surface quality.

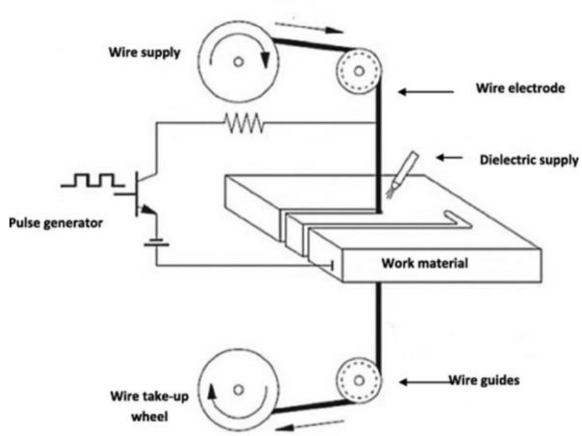

Figure 1 Working Principle Wire cut EDM Process [11]

The CNC type Wire EDM AGIE CHARMILLES CUT 200MS model (refer Figure 2) employed for this investigation. The Figure 1b shows the experimental setup with control system. The details of experimental setup furnished in Table 2.

Table 2 – Technical Specification of CNC type Wire EDM

Technical Description	**Technical Specification**
Model	AGIE CHARMILLES CUT 200MS
Control Type of Wire EDM	Computer Numerical Control (CNC)
Travels in Longitudinal Directions	13.780 inches
Travels in Transverse Directions	08.867 inches
Travels in vertical Directions	08.867 inches
Maximum weight of Work piece	1653.45 lbs
Taper Angle Height	30/8.66^{o}

Figure 2. Experimental Facility

2.3 Surface Quality Measurement

The surface quality is measured in surface roughness that texture of the surface. It is generally height variation on surface from its ideal. If the height variation is more means its roughness else smoothness. The degree of smoothness is surface quality. In other words it is a measure of surface irregularity. The importance of surface quality is the irregularities are nucleation sites for corrosion and crack. The Figure 3 shows the profile-meter utilized in this investigation.

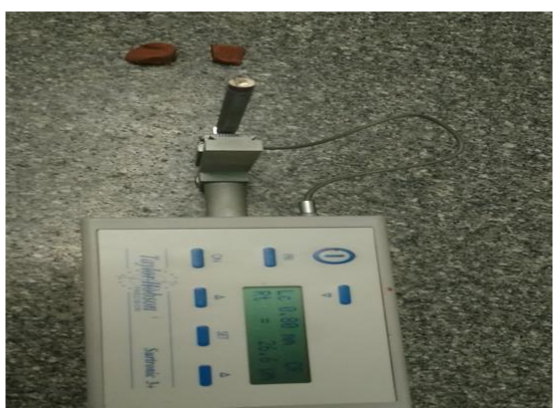

Figure 3 Surface Roughness Tester (profile-meter) – For surface quality measurement

3 EXPERIMENTATION

3.1 Experimental Design

Taguchi L9 orthogonal array (Shown in the Table 4) was preferred for experimental design. Nine different 5 mm thick square specimens of side 10 mm were prepared and used for investigation. The surface quality is measured in terms of surface smoothness (minimum Roughness). Hence digital type Taylor Hobson make roughness tester (Figure 3) is employed for investigate the surface quality by measure of surface roughness. The factors are $\boldsymbol{P_{ON}}$, $\boldsymbol{P_{OFF}}$ On $\boldsymbol{W_T}$ and $\boldsymbol{W_F}$. The levels of parameters were decided by prelude experiments. The zinc coated brass wire preferred

Table 3 WEDM parameters and their range of variation

Machining Parameters of WEDM	**Minimum Level**	**Intermediate Level**	**Maximum Level**
Wire Feed Rate (F) in mm per minute	4	6	8
Pulse on Time (T_{ON}) in micro seconds	1	2	3
Wire Tension (T) in Newton	1.4	1.6	1.8
Pulse off Time (T_{OFF}) in micro seconds	4	8	12

The parameters shown in the tables are varied at three levels while other parameters kept as constant. The electrode gap 0.35mm and wire diameter 0.25 mm. End of each trail experiments the roughness. Hence the range and level of parameters identified. The four identified parameters (I=4) and their minimum intermediate and maximum levels (L=3) are presented in the Table 3. The responses decided to verify the quality of machining that is performance of machining 12X18H10T - Stainless Steel is Roughness of the machined surface (Ra). The number of experiments can be obtained by the numerical relation of [(L-1) x I] +1 and obtained 9 experiments. The MINITAB Version 17 software is employed for detailed design for conducting experiments and performing statistical investigation on its results. The particulars of Experiments which designed are shown in the Table 4.

3.2 Experimentation

The 0.25 millimeter diameter brass with zinc coated wire fitted in the Wire EDM machine and ensured the tenstion and feed adjustments working conditions. Before loading into the WEDM machine, the weight of the weight of the work piece as well as weight of the wire bunch weighed. The 12X18H10T - Stainless Steel work piece mounted on the work table and clamped well. The reference point on the work material set to fix the work coordinate system. With respect to the work material reference point in the work coordinate system the machining operations are is programmed on the CNC. As usual one of the edge was preferred to define the reference point in this case the left corner of the nearest edge of the operation (who stand in front of the machine to operate) was defined. The machining was carried out as per the experimental design the machining on 12X18H10T - Stainless Steel work pieces carried out and the constant machining time of 10 minutes maintained for all experiments. After complete the surface machining the work piece removed, cleaned and its surface quality was examined. The average of surface quality measured at various points randomly on the work material was considered for analysis. Each of nine experiments conducted same quality work material exclusively. The machined samples in WEDM as per DOE are shown in the Figure 4. The observed surface quality consolidated experiment wise in the Table 4.

Figure 4. Experimented Samples as per order of Experiment

Table 4. Taguchi Experimental Design and Experimented observations

S.No. of Expt.	Wire Feed Rate (F) in mm/min	Pulse on Time (T_{ON}) in µs	Wire Tension (T) in N	Pulse off Time (T_{OFF}) in µs	surface quality (Ra) in µm
Expt. No. 1	4	1	1.4	4	2.43
Expt. No. 2	4	2	1.8	8	2.54
Expt. No. 3	4	3	1.6	12	2.41
Expt. No. 4	6	1	1.6	8	2.54
Expt. No. 5	6	2	1.4	12	2.31
Expt. No. 6	6	3	1.8	4	2.95
Expt. No. 7	8	1	1.8	12	2.39
Expt. No. 8	8	2	1.6	4	2.51
Expt. No. 9	8	3	1.4	8	2.67

4. RESULTS AND DISCUSSION

In the MINITAB 17 software, for computing the signal to noise ratio, it was set that for surface quality minimum surface roughness is preferred so 'Lower the Better' option for Surface roughness Ra.

4.1 Taguchi Analysis on Surface Quality (Ra)

The power of control of identified factors on surface quality (Ra) in terms of surface roughness on machined surface can be investigated statistically by means of S/N (Signal to Noise) ratio. Statically obtained ratios from the software are presented in the Table 5. The rank matrix for analyzing the power of factors (Identified parameters) on surface Quality (Ra) is shown in Table 6. The mean effect plot for surface roughness is shown in the Figure 5. It is to be noted that the lowest value of surface roughness offers highest smooth on surface.

Table 5. The Statistics of S/N (Signal to Noise) ratio for Surface Quality (Ra)

Specimen	Surface Roughness (Ra)	Signal to Noise Ratio
1	2.43	-7.67631
2	2.54	-802801
3	2.39	-7.53154
4	2.54	-7.95880
5	2.31	-8.09667
6	2.51	-7.23456
7	2.41	-9.36695
8	2.95	-8.56270
9	2.67	-7.67631

Table 6 Rank matrix for Power of Factors on surface Quality (Ra)

Level	P_{ON} in µs (A)	P_{OFF} in µs (B)	W_F in mm/min (C)	W_T in N/ mm^2 (D)
1	-7745	-8.334	-7.825	-7.816
2	-7.763	-8.229	-7.888	8.210
3	-8.535	-7.481	-8.332	-8.018
Delta	0.790	0.853	0.507	0.393
Rank	2	1	3	4

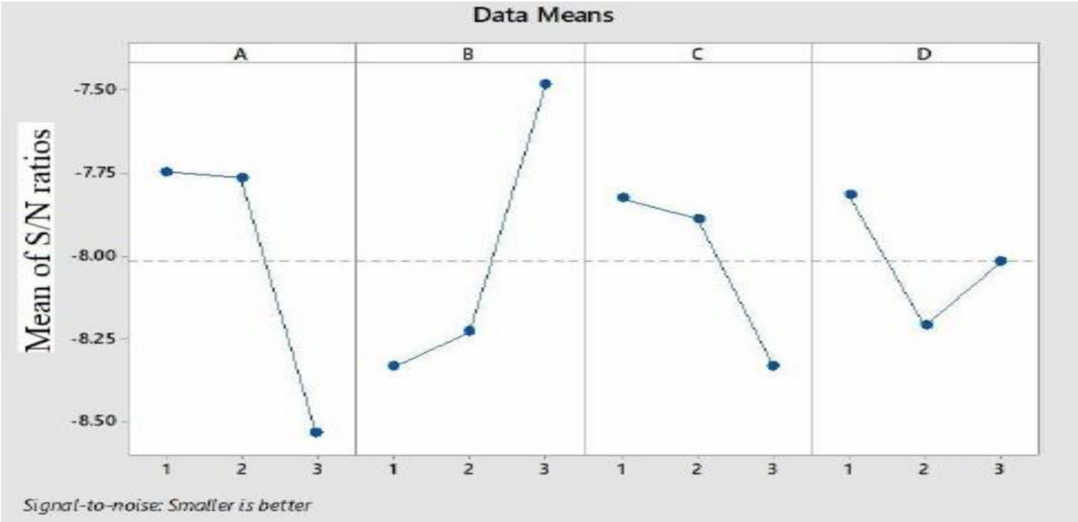

Figure 5. Mean Effect Plot of Signal to noise Ratio for Surface Roughness

Most Influential Parameter on Surface Quality

The percentage contribution of parameters on each response was obtained from analysis in MINITAB software and the pie diagram (Figure 6) was plotted in Microsoft excel as per obtained data. The Surface Quality (***Ra***) Results of ANOVA is furnished in the Table 7. In which DoF mean Degree of Freedom, SS mean Sum of Squares and MS is Mean Squares

Table 7. Surface Quality (***Ra***) Results of ANOVA

Process Parameters (Source)	*DoF*	SS	MS	F-statistics	Percentage of Contribution
T_{ON}	2	0.11209	0.05604	1.88	38.55
T_{OFF}	2	0.11129	0.05564	1.86	38.27
W_T	2	0.04329	0.02164	0.52	14.88
W_F	2	0.02409	0.01204	0.27	8.28
Error	6	-	-	-	-

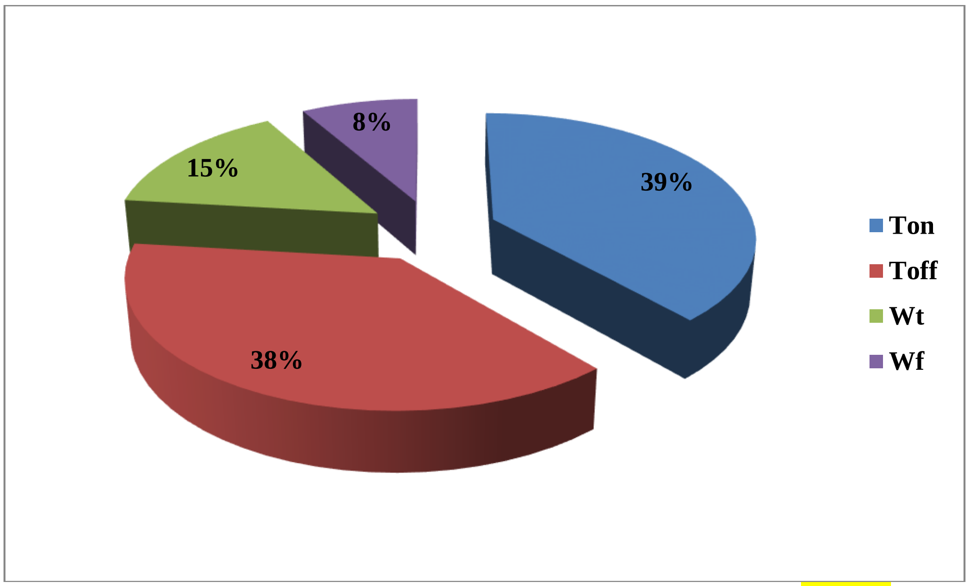

Figure 6: Power of control in percentage of identified parameters on Surface Rough

Mathematical modeling for parameter Prediction

The result of factorial experiment, is utilizing to identify the most influencing parameter value for obtaining the desired surface quality. So the factorial experiment was conducted by varying the most influential parameter values to obtain corresponding values for responses. The P-OFF is most influencing factor on the surface quality. Five experiments conducted by varying the P-OFF and corresponding surface quality value (Ra) observed, The average of three measurements of each conducted trails tabulated in the Table 8. Hence a separate graph plotted for surface roughness variations with respect to P-OFF (refer Figure 7). The average line was produced to predict the possible values for the required surface roughness value. From the data governing equation was generated.

Parameter prediction for R_a

P_{ON} = 1.5 µs
W_T = 1.7 N/mm^2
W_F = 5 mm/min

The equation generated based on relation between P-OFF and R_a is

Ra= -0.0011(Poff)^2 + 0.0531(Poff) + 3.0925

The average line on Surface roughness is Y= 0.0011x2+0.0531x+3.0925

The equation generated based on relation between P-OFF and R_a is

$$R_a = -0.0011(P\text{-}OFF)^2+0.0531(P\text{-}OFF)+3.0925$$

Table 8. Experimented Results of $\boldsymbol{R_a}$ for $\boldsymbol{P_{OFF}}$

P_{OFF} (µs)	R_a (µm)
4	2.84
6	2.94
8	2.5
10	2.52
12	2.36

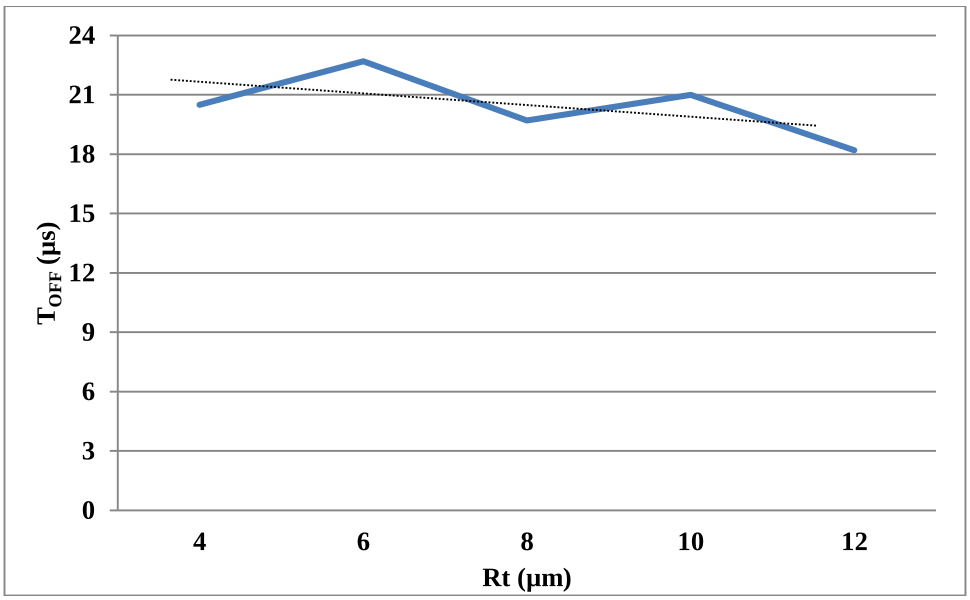

Figure 7 P_{OFF} Prediction for desired surface quality

CONCLUSION

The surface quality aspect of machine-ability study on the12X18H10T - Stainless Steel work material in the process of wire electrical discharge machining was investigated. Taguchi L9 orthogonal array based experimental design was derived as per number of process variables namely Pulse off Time, Wire Tension, Pulse on Time, and Wire Feed Rate. The experimented values utilized to perform the Taguchi Analysis and identified the most influencing factor is Pulse off Time. The trend of variation of surface roughness was measured with respect to Pulse off Time variation and established the mathematical model to predict the roughness value with respect to pulse of time setting.

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