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# Pilot Study of Wire EDM on Cryo-treated H13 Tool by using RSM

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**ABSTRACT:** This paper untangle the sequel of individual process parameters of Wire Electrical Discharge Machining (WEDM) like Pulse On (TON), Pulse Off (TOFF), Peak Current (IP) which has been scrutinized to ramification on surface roughness (RA) of Cryo-treated H13 tool steel on WEDM by using Response surface methodology (RSM). The Box Behnken Design (BBD) was used for preparing the experiments. The optimum set of input parameters for maximum surface roughness (RA) has been determined. It has been rummage that, Pulse on evinces prominent performance for increasing RA. Cryogenic treatment helps to transform retained austenite into martensite. The result was analyzed by Regression method using analysis of variance (ANOVA) method.

**KEYWORDS:** ANOVA, BBD, Cryogenic treatment, RA, RSM

### I. INTRODUCTION

As manufacturers solicit materials that consist bountiful service life, wear-resistances, toughness, superior thermal conductivity and insensitiveness to hot cracking and more efficient. Hence it is easy to perceive that such materials should be highly advanced to achieve elaborate productivity. The difficulty is to choose such material which emerges in form of efficiency and commendable service life. The best credible solution to this issue is adhering to cryogenic treatment. Exploiting Cryogenic treatment can obtain enhancing hardness, toughness and tool life leads to fine microstructure. The innumerable use of WEDM dueto ability to make complex shapes with hard materials and alloys. To investigate WEDM performance measures such Surface roughness (RA). To implement the intendresearch problem, we are going to outline experiments by using BBD method and analysis by ANOVA. This exercise consists of innumerable of control factors and their stochastic nature owing to which it is a challenging task to achieve optimal performance against the in tail response.[4] [16]

### II. RELATED WORK

Adem et al [1] have investigated the effects of cryogenic treatment on the mach inability of hardened and cryo-treated tool steel, a number of investigations were performed on the hard turning of cryo-treated AISI H13 hot work tool steel with two ceramic inserts under both dry and wet cutting conditions in three categories Conventional Heat Treated (CHT), Cryo-Treated (CT) and Cryo-Treated and Tempered (CTT). Experimental results showed that the lowest wear and surface roughness (Ra) values were obtained in the turning of the CTT samples. It was observed that the Fc values decreased with increasing cutting speed and substantially increased with increasing feed rate. Similar trends were also observed in Ra graphics. However, Ra and Fc values slightly increased due to rapid tool wear at the highest cutting

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speed (300 m/min). In addition, the lowest Fc and Ra values were obtained in the turning of the CTT samples due to the decreases in hardness and improvements in mechanical and micro-structure. [1] Mahdi et al [3] explained Cryogenic treatment at  $-72^{\circ}\text{C}$  and deep cryogenic treatment at  $-196^{\circ}\text{C}$  was applied and it was found that by applying the subzero treatments, the retained austenite was transformed to martensite. As the temperature was decreased more retained austenite was transformed to martensite and it also led to smaller and more uniform martensite laths distributed in the microstructure. The deep cryogenic treatment also resulted in precipitation of more uniform and very fine carbide particles. The micro structural modification resulted in a significant improvement on the mechanical properties of the H13 tool steel. The most important effect of tempering the deep cryogenically treated samples was the improving of the wear properties of the H13 tool steel. [3] In deep cryogenic treatment (DCT)  $-196^{\circ}\text{C}$  for 24 hours have been shown significant improvement on micro structural modification and mechanical properties of H13 tool steel. [1-4], [9]. Cryogenic treatment shows improvement in wear resistance. [12]. In micro-structural modification treatment reduces the retained austenite content is very convenient as it enhances dimensional stability [4]. Experimentally investigation the effect of various input parameters of WEDM on RA and MRR. Relationship between responses and input parameters are analysed by using ANOVA. [5-7] The fundamental and analytical of Box Behnken Design (BBD). Harvinder et al [5] have experimentally investigated the effects of various WEDM variables on Surface Roughness of AISI H13 using ANOVA method. The effect of all the input parameters on the output responses have been analyzed using analysis of variance (ANOVA). Plots of S/N ratio have been used to determine the best relationship between the responses and the input parameters. The surface roughness was found to be minimum with diffused wire and maximum with plain brass wire. The surface roughness increases with increase in pulse on time. The surface roughness decreases with increase in pulse off time, peak current, servo voltage, and flushing pressure. As the wire tension increases, the surface roughness first decreases and then increases with further increase in wire tension. As the wire feed rate increases, the surface roughness first increases and then decreases. As the servo feed rate increases, the surface roughness initially decreases and then increases with increase in servo feed rate [5]. J. Udaya et al [6] had approached for optimization on WEDM variables on multiple performance characteristics of AISI H13 using ANOVA method. The effect of all the input parameters on the output responses have been analyzed using analysis of variance (ANOVA). [6] Pathya et al [7] explains optimization of recast of layer thickness the surface roughness simultaneously in a WEDM process by using Taguchi method with Fuzzy LOGIC has been applied of AISI H13 STEEL with multiple performance characteristics such as MRR & SR [7]

As the summary of related work is most of research was done on study of different types of heat treatments on H13 tool steel, changes in microstructure as well as properties of H13 tool steel. Almost research paper shows the effect of input parameters on RA and MRR of Non Cryo –Treated H13 tool steel on WEDM by using Taguchi method and Optimization was performed by ANOVA .

## III. EXPERIMENTAL DETAILS

### 3.1 Material Selection

Cryo-treated H13 hot work tool steel has high ardent tensile strength, fiery wear-resistance and toughness. Good thermal conductivity and insensitiveness to hot cracking. It is the exercise of treating material to cryogenic temperatures  $-196^{\circ}\text{C}$  for 24 hr [1][3][4] to remove residual stresses and improve wear resistance on steels. The procedure has an extensive range of applications from industrial tooling to improvement of musical signal transmission. [14]

TABLE NO. 1.1: CHEMICAL COMPOSITION OF CRYO TREATED AISI H13 TOOL STEEL

El	C	Mn	Si	Mo	Cr	V	S	P	Ni	C u	Fe
%	0.320	0.200	0.800	1.100	4.750	0.800	0.030	0.030	-	-	Bal
	To	To	to	To	To	To					
	0.450	0.500	1.200	1.750	5.500	1.200					

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Table No. 1.1 shows various chemical composition of AISI H13 tool steel. It is the process of treating material to cryogenic temperatures (-196°C) for 24 hr to remove residual stresses and improve wear resistance on steels.

### 3.2 Schematic of Machining

The experiments were conducted on a wire-cut EDM machine ELEKTRA SPRINTCUT 734. The size of work – piece is 10mm\*10mm\*16 mm. The brass wire with 0.25 mm diameter was used as electrode in experiment.

*Table No.1.2 WEDM 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 traverse (X, Y): 300, 400 mm	Auxiliary table traverse (u, v) : 80, 80 mm
Wire Electrode diameter: 0.25 mm (Standard)	Generator: ELPULS-40 A DLX
Controlled axes: X, Y, U, V	Simultaneous: independent
Interpolation: Linear & Circular	Input Power supply: 3 phase, AC 415 V, 50 Hz
Connected load: 10 KVA	Average power consumption: 6 to 7 KVA

Table No. 1.2 exhibits WEDM’s miscellaneous specifications such as design, table’s size, Max. Work piece height & weight, table traverse, wire Electrode diameter, controlled axes etc that are used to effectuate this experiment.

*Table No.1.3: Different coding input variables*

Parameter	Symbol	Coded factor	-1	0	1
Pulse on time (µs)	Ton	A	115	120	125
Pulse off time (µs)	Toff	B	40	50	60
Peak Current (A)	IP	C	140	170	200

The different coding variables are used in the experiment are depicted in TableNo 1.3 In the experiments conducted with the combination of machining parameter are presented in Table No.1.3.

## IV. RESPONSE SURFACE METHODOLOGY (RSM)

By careful design of experiments, the objective is to optimize a response (output variables) which is influenced by several independent variables (input variables). To determine the interactions of the factors Response Surface Methodology (RSM) was used. The pertinent process parameter has selected for the present investigations are pulse on time, pulse off time and peak current on the material removal rate (MRR) during the WEDM process. The Box Behnken Design (BBD) has been implemented for this study with three variables in total 15 runs. [15]

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### 4.1 Box Behnken Design (BBD)

The Box Behnken Design (BBD) has been implemented for this study with three variables in total 15 runs. [15] By using Minitab 18 software.

FACTORS: 3

BASE RUNS: 15

BASE BLOCKS: 1

CENTRE POINTS: 3

REPLICATES: 1

TOTAL RUNS: 15

TOTAL BLOCKS: 1

*TABLE NO.1.4 DESIGN TABLE*

Run	Blk	A	B	C
1	1	-1	-1	0
2	1	1	-1	0
3	1	-1	1	0
4	1	1	1	0
5	1	-1	0	-1
6	1	1	0	-1
7	1	-1	0	1
8	1	1	0	1
9	1	0	-1	-1
10	1	0	1	-1
11	1	0	-1	1
12	1	0	1	1
13	1	0	0	0
14	1	0	0	0
15	1	0	0	0

Table No1.4 used to demonstrate the study of Box Behnken Design with three variables in total 15 diverse runs.

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## V. EXPERIMENTAL RESULTS AND DISCUSSION

### 5.1 Analysis of RA

REPOSE SURFACE REGRESSION: RA VERSUS TON, TOFF & IP

*TABLE NO. 1.5 ANALYSIS OF VARIANCE OF RA*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	10.9964	1.83273	27.14	0.000
Linear	3	5.1022	1.70073	25.18	0.000
A	1	0.6944	0.69444	10.28	0.012
B	1	1.0967	1.09668	16.24	0.004
C	1	3.0781	3.07807	45.58	0.000
Square	3	4.6859	1.56197	23.13	0.000
A*A	1	0.6903	0.69027	10.22	0.013
B*B	1	0.7741	0.77409	11.46	0.010
C*C	1	3.0534	3.05340	45.21	0.000
Error	8	0.5403	0.06753		
Lack-of-Fit	6	0.5403	0.09004	*	*
Pure Error	2	0.0000	0.00000		
Total	14	11.5366			

Table No. 1.5 shows contribution of TON, TOFF and IP on surface roughness (RA). It also shows error, lack of fit, pure error and total effect of individual and combine input parameter on RA .

*Table No. 1.6 Model Summary*

S	R-sq	R-sq(adj)	R-sq(pred)
0.259868	95.32%	91.80%	81.27%

Table No. 1.6 gives model summary of ANVOA of Ra vs TON, TOFF and IP

*Table No. 1.7 Coded Coefficients*

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-261.4	78.6	-3.32	0.010	
A	4.16	1.30	3.21	0.012	4993.00
B	-0.546	0.136	-4.03	0.004	217.67
C	0.3455	0.0512	6.75	0.000	279.30
A*A	-0.01730	0.00541	-3.20	0.013	4993.01
B*B	0.00458	0.00135	3.39	0.010	217.68
C*C	-0.001010	0.000150	-6.72	0.000	279.31

Table No. 1.7 represents coded coefficients and there values of TON, TOFF and IP

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Table No. 1.8 Fits and Diagnostics for Unusual Observations

Obs	RA	Fit	Resid	StdResid	
9	2.835	3.290	-0.455	-2.48	R

Table No. 1.8 gives observations for fits and diagnostics

Regression Equation in Uncoded Units

$$RA = -370 + 0.999 A - 0.0592 B + 0.01190 C - 0.000692 A*A + 0.000046 B*B - 0.000001 C*C$$

Table demonstrates the ANOVA for RA and it is recommended that the square – linear quadratic model is statically significant for analysis of RA. Table demonstrate the value of R<sup>2</sup>, adjusted R<sup>2</sup> and predicted R<sup>2</sup> is more than 81%. It means the paradigm acquired can be avail for future outgrowth. The difference between adjusted R<sup>2</sup> and predicted R<sup>2</sup> is less than 20%. This dissimilarity manifests unimpeachable results. The p-value for the exemplar is lower than 0.05 which indicate that the exemplary apprise to be statically outcome.

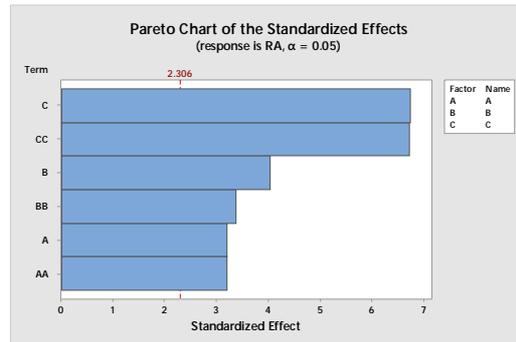


Chart No1.1 Pareto Chart of the Standardized effect on RA

Chart No1.1 Pareto Chart of the Standardized effect on RA according to the ascending order as IP, TOFF and TON

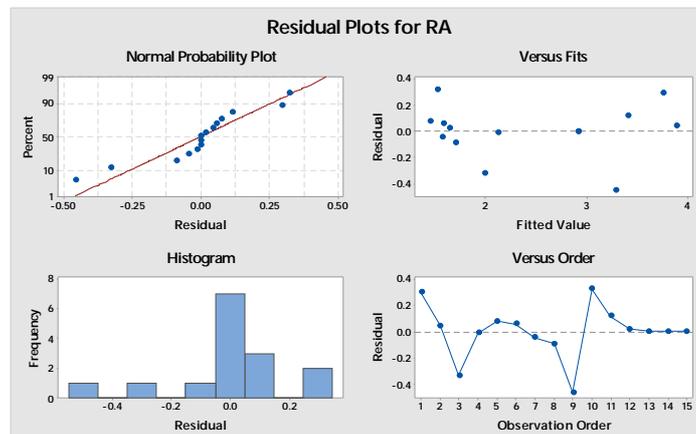


Chart 1.2 Residual Plots for RA



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