EXPERIMENTAL INVESTIGATION OF EROSION RATE OF CRYOGENIC TREATMENT OF AISI D2 TOOL STEEL UNDER WIRE EDM

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ABSTRACT

WEDM (Wire electric discharge machine) is a thermal electric spark erosion machine process which cut hard conductive material by using a wire electrode. Cryogenic treated AISI D-2 tool steel (high carbon high chromium tool steel) was used for the investigation. In Cryogenic treatment the material is placed in Liquid nitrogen environment maintained below -190°C which remove stress and improve the wear resistance. Samples are machined with wire EDM by using Taguchi method for robust design. The $L_9\ (3^4)$ Orthogonal array was used. The input process parameters are Peak Current, Servo Voltage, Wire Tension and Duty Cycle. Out of all the parameters Duty Cycle has the maximum effect on Erosion Rate.

I. INTRODUCTION

In cryogenic treatment the work piece is gradually cooled in the range −190°C, which may vary in reference to cost and type of application. It gives various advantages like increase in wear resistance, reduced residual stresses, increase in hardness, fatigue resistance, toughness imparted by transformation of retained austenite to martensite, precipitation of carbides, eta-carbide formation, perfect distributed/homogenous crystal structure, better thermal conductivity, and reduced chemical degradation [1]. The Wire Electric Discharge Machining (WEDM) is a type of EDM and is commonly known as wire-cut EDM. In the process, a thin metallic wire is fed on-to the work piece, which is submerged in a tank of dielectric fluid such as deionized water. In the WEDM process, water is used as the dielectric fluid in general. It is filtered and de-ionized by units which controls the resistivity and other electrical properties.

II. LITERATURE REVIEW

Kashif Ishfaq et al [2018] found through experiment that pulse on time and pulse off time should be kept high priority in order to get the desired results in response variable (surface roughness, included angle, clearance angle and material removal rate) [2].

Vikram Singh et al [2017] they drawn these conclusion on the basic of their experiments:

- They developed the regression equation for the mathematical models for gap current, cutting rate, gap voltage, SR, and MRR.
- The main significant factors that affect the cutting rate are pulse on time, pulse off time, and servo voltage [3].

Rakesh Bhandari et al (2017) performed research to evaluate the relation between input parameters and metal removal rate. He uses $L2_{7}3^{5}$ Taguchi orthogonal Array Matrix. The Minitab and design of experts Software was used to analyze the data collected so forth. He found that

- Input parameter pulse of time was leading the other factors by a contribution of 37.28%. It was followed by pulse on time with contribution of 33.48 %, servo voltage was contributing 26.40 %, wire feed was contributing 2.01 % and peak current was contributing 0.83 %.
- He also develop the model which relates the relationship amongst the input process parameter and response parameter [4].

Barun Kumar et al (2017) the researcher investigated and optimize the input process variables of wire-cut electric discharge machine by Grey relational method (GRA). He selected AISI D2 tool Steel. D2 Die steel is a high carbon, and High chromium tool steel which is used for producing dies and punches. He selected EZECUT PLUS WIRE EDM (RRAPT) as the machine. The Input process variable he selected was Wire feed rate, Pulse on time, Pulse off time, Peak current, and Servo voltage. Response variable were Material removal rate, Kerf width, Surface roughness. He selected Taguchi technique and select L18 orthogonal array matrix for design of experiment. He then applied Grey relational analysis for optimization. The main conclusion he draws are

- while considering the Metal removal rate the percentage contribution of pulse on time was 72.12%, pulse off time was 14.4 8%, Wire feed rate is 4.93%, Servo voltage was 2.15%, Peak current was 1.80% and the error was 4.52% [5].

M. Manjaiah et al (2016) The AISI D2 steel was investigated under the wire electro discharge machining (WEDM). The Response variables or performance characteristics MRR and surface roughness were optimized by Taguchi technique. The input process parameter selected were pulse on time, pulse off time, servo voltage and wire feed. The Taguchi L27 orthogonal array matrix was selected for conducting the experiment. Multi-objective optimization was used by utilizing Taguchi based technique approach to optimize MRR and Ra. it was found that found that the pulse on time and servo voltage are the most significant parameters affecting MRR and Ra. This is because the increased pulse on time has higher electrode discharge energy, causes more melting and formation of deeper crater on the machined surface [6].

Amanpreet Singh et al (2016) found that

- With plain brass wire obtained from ANOVA. It is observed that Pulse on time, Pulse off time are contributing factors which influence the MRR.
- For zinc-coated brass wire, the significant factors for MRR, Pulse on time, Pulse off time [7].

Sanjay Kumar Majhi et al [2014] the scholar researched the effect of input variables on the response or output parameters In Electric Discharge machine. He took input variables such as pulse current, pulse on time and pulse off. The output variables are Metal Removal Rate, Tool Wear Rate, and Surface Roughness. The material selected was D2 tool steel. He used Gray Relational Analysis (GRA) and Response Surface Methodology (RSM). The output of his research was that pulse on time and pulse off time significantly affect the metal removal rate when using copper as electrode [8].

Vikram Singh et al [2014] In this work, three performance parameters (Cutting rate, Surface Roughness and Material Removal Rate) are investigated by varying the four Process (machining) parameters on AISI D2 steel with Brass wire as electrode in wire electric discharge machine. The performance parameters included pulse on time, Pulse off time, Servo voltage (SV) and Wire feed rate (WF). Experiments were conducted according to L27 Orthogonal Array Design. The optimum parameters value combination was found which would yield minimum Surface Roughness and maximum Material Removal Rate & Cutting Rate. The following conclusions have been drawn:

- The two main significant factors that affect the Cutting rate are Pulse on time and Pulse off time respectively [9]

III. EXPERIMENTAL SETUP

3.1 WORKPIECE MATERIAL

AISI D2 Tool steel was used as work piece material. Sample of size 20mm × 20mm × 35mm were prepared by using wire EDM. The sample are then cryogenic treated with soaking time of 7 hours. The following table shows the chemical composition of work piece material.

Table 3.1 – Chemical composition of AISI D2 Tool steel

C	SI	Cr	Mo	V
1.50%	0.30%	12.00%	0.80%	0.90%

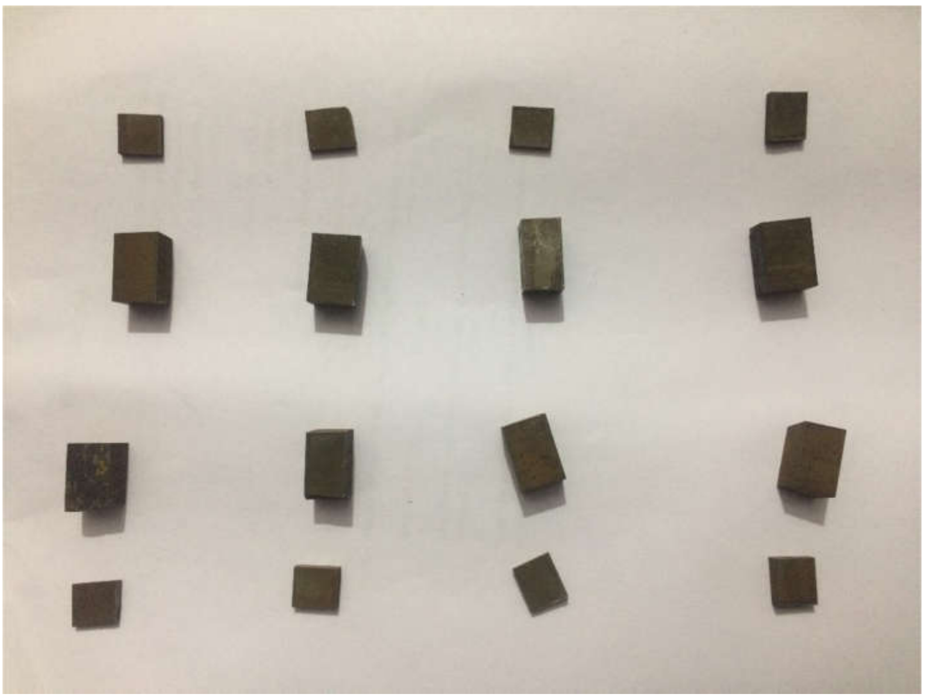


Figure 3.1: AISI D2 Tool Steel Material

3.2 WIRE EDM AND SURFACE ROUGHNESS TESTER

Elektra ELPLUS 40A DLX wire EDM machine was used. Distilled and demineralized water was used as dielectric. The brass wire was used to cut the samples.

3.3 INPUT PARAMETERS

The input parameters are peak current, servo voltage, wire tension and duty cycle. The Taguchi matrix $L_9\,(3^4)$ Orthogonal array was used. The various levels and values of the input and output parameter are shown in the table

Table 3.2 Taguchi L9 Orthogonal array

Run	Peak Current (A)	Servo Voltage (V)	Wire Tension	Duty Cycle
R1	90	20	6	68
R2	90	30	9	72
R3	90	40	12	75
R4	130	20	9	75
R5	130	30	12	68
R6	130	40	6	72
R7	170	20	12	72
R8	170	30	6	76
R9	170	40	9	68

The samples are cut and then the values of Erosion Rate are measured. Single pass was used to process the samples in wire EDM.

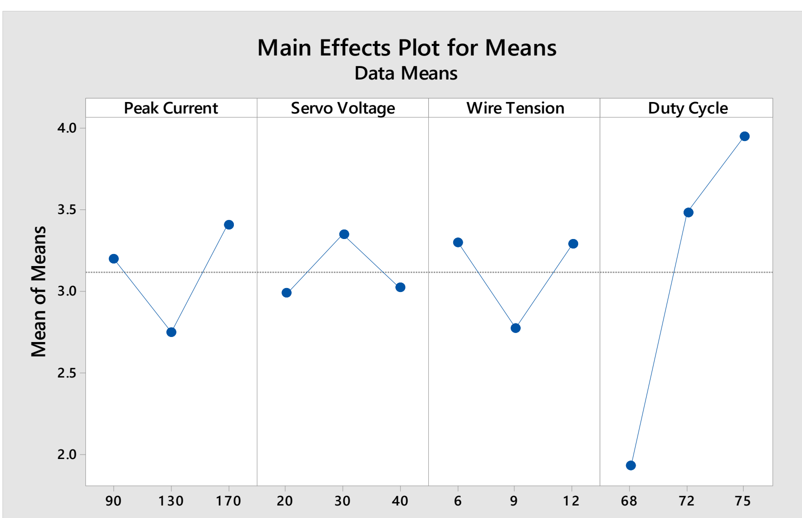
IV. RESULTS

After measuring the values of erosion rate of each samples, the table 4.1 can be drawn. The Response table is shown in table 4.2. The MiniTab 18 [8] is used to get the graphs of main effects plot for means and main effects plot for SN Ratios. Both of which are 4.1 and 4.2 shown respectively.

Table 4.1 - Taguchi Matrix showing input and output parameters

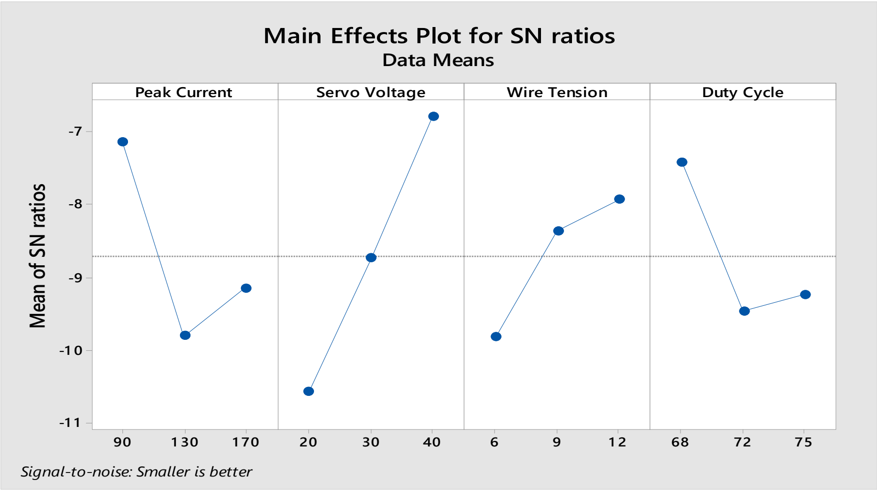
Run	Peak Current (A)	Servo Voltage (V)	Wire Tension	Duty Cycle	Erosion Rate (mm/min)
R1	90	20	6	68	2.05
R2	90	30	9	72	3.45
R3	90	40	12	75	4.10
R4	130	20	9	75	3.1
R5	130	30	12	68	1.95
R6	130	40	6	72	3.20
R7	170	20	12	72	3.81
R8	170	30	6	76	4.65
R9	170	40	9	68	1.77

Figure 4.1 - Graph showing the values main effect plot for means



From Figure 4.1, the erosion rate first shows decrement and then increment as the value of peak current increases. The servo voltage has also similar type of effect on erosion rate. However the effect of wire tension, in overall, close to almost nil. The duty cycle has the far most significant impact on erosion rate.

Figure 4.2 - Graph showing the main effects plot for SN Ratios



The response table obtained from MiniTab 18 can be drawn as

Table 4.2 - Response table

Level	Peak Current	Servo Voltage	Wire Tension	Duty Cycle
1	9.749	9.227	9.896	5.665
2	8.577	9.969	8.514	10.826
3	9.976	9.106	9.892	11.811
Delta	1.399	0.863	1.381	6.146
Rank	2	4	3	1

The response table 4.2, shows the Priority of the variables, as duty cycle has most significant effect on erosion rate values followed by peak current, servo voltage and wire tension respectively.

V. CONCLUSIONS

In this work, performance parameter (Erosion Rate) is investigated by varying the four Process (machining) parameters on AISI D2 steel with Brass wire as electrode in wire electric discharge machine. The input performance parameters included peak current, duty cycle, Servo voltage and Wire tension. Experiments were conducted according to L9 Orthogonal Array Design. The following conclusions have been drawn:

- For the erosion rate the order of priority with their contribution is duty cycle, peak current, servo voltage then is followed by wire tension.
- There is frequent breakage of wire in Run R4 due to high value of current.

VI. REFERENCES

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