# EXPERIMENTAL INVESTIGATION OF SURFACE ROUGHNESS 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 Servo Voltage has the maximum effect on surface roughness.

## 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 workpiece, 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.

The various application of WEDM includes aerospace, medical, electronics and semiconductor applications, tool & die making industries, for cutting the hard extrusion dies etc.

## II. LITERATURE REVIEW

Vikram Singh et al showed that pulse on time is the major influencing factor (contributing 62.03 % to performance measures), followed by servo voltage (contributing 31.68 %), wire feed (contributing 4.90 %), pulse off time (contributing 1.18 %), and peak current (contributing 0.21 %) [2].

Pankaj R. Patil et al showed that among the three process parameters (pulse on time, pulse off time and current)

- For cutting of WPS D2 material current has significant effect on Quality Characteristic.
- For work piece D2 material maximization of current gives maximum surface finish of component [3]

U.K.Vates et al found that factor Pulse on time is the most significant factor and Spark gap voltage is significant factors where as Pulse off time is the least significant factor in improving the surface roughness [4].

Neeraj Sharma et al found that

- The increase in pulse on-time and servo voltage surface roughness increases. With the increase of peak current the slope of surface roughness curve observed to be declined.
- From ANOVA it is found that pulse on time and servo voltage has the maximum percentage contribution while processing cryogenically treated D-2 tool steel as compared to pulse off time and peak current [5].

M. Manjaiah et al 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].

Rakesh Bhandari et al The main significant factors that affect the Surface Roughness are Pulse on time and Servo Voltage [7].

Barun Kumar et al found that in evaluating the surface roughness, the percentage contribution of Wire feed rate is 1.40%, Ton is 71.04%, Toff is 6.63%, Peak current is 8.98%, Servo voltage is 7.63%, and error is 4.32%. This error is due to machine vibration. Thus pulse on time is the greatest effect on surface roughness followed by current and servo voltage [8].

Amanpreet Singh et al found that

- With plain brass wire obtained from ANOVA. It is observed that $T_{on}$, $T_{off}$ and Servo Voltage are contributing factors which influence the surface roughness.
- For zinc-coated brass wire, the significant factors for surface roughness, $T_{on}$, $T_{off}$ and Servo Voltage [9].

I. K. Chopde et al investigated the effect of pulse on time, pulse off time, spark gap voltage and peak current are experimentally in wire electro discharge machining of cryo treated AISI D 2 tool steel. The factor Pulse on time is the most significant factor and Spark gap voltage and Peak current are significant factors where as Pulse off time is the least significant factor in improving the surface roughness. [10].

## III. EXPERIMENTAL SETUP

### 3.1 WORKPIECE MATERIAL

AISI D2 Tool steel was used as work piece material. Sample of size $20mm \times 20mm \times 35mm$ 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 2.1 – Chemical composition of AISI D2 Tool steel

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

### 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 3.1 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 surface roughness are measured. Single pass was used to process the samples in wire EDM.

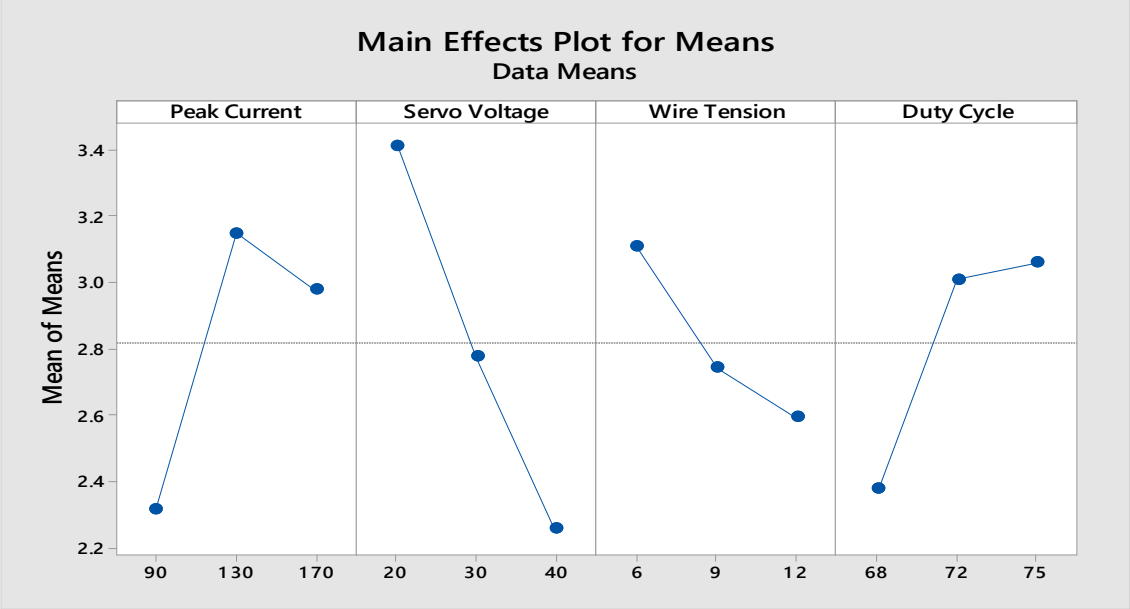
## IV. RESULTS

After measuring the values of surface roughness of each samples, the table 4.1 can be drawn. The Response table is shown in table 4.2. The MiniTab 18 [11] 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 | SR Values (um) |
|---|---|---|---|---|---|
| R1 | 90 | 20 | 6 | 68 | 2.77 |
| R2 | 90 | 30 | 9 | 72 | 2.403 |
| R3 | 90 | 40 | 12 | 75 | 1.78 |
| R4 | 130 | 20 | 9 | 75 | 3.92 |
| R5 | 130 | 30 | 12 | 68 | 2.45 |
| R6 | 130 | 40 | 6 | 72 | 3.08 |
| R7 | 170 | 20 | 12 | 72 | 3.55 |
| R8 | 170 | 30 | 6 | 76 | 3.48 |
| R9 | 170 | 40 | 9 | 68 | 1.91 |

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

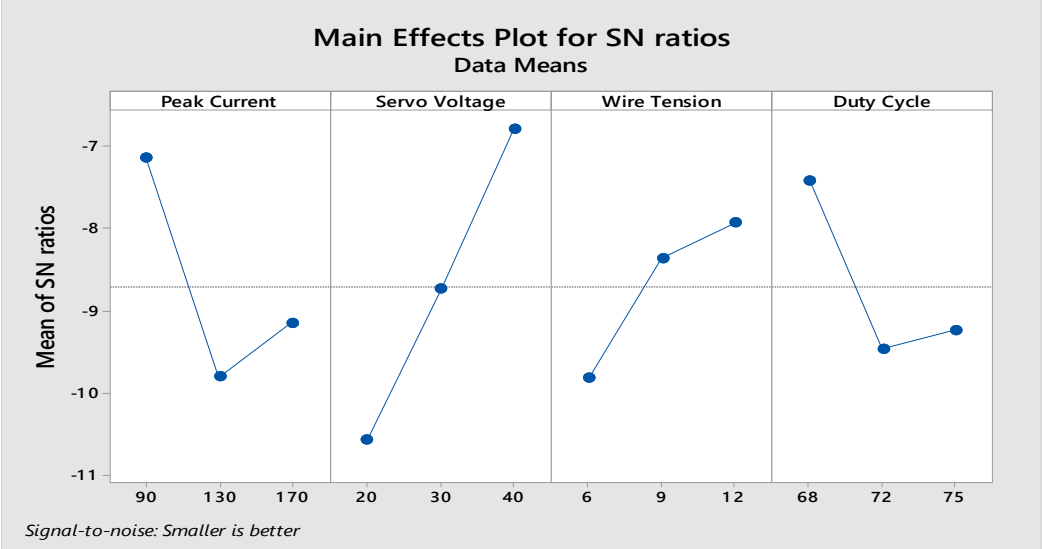



The response table obtained from MiniTab 18 can be drawn as

Table 4.2 - Response table

| Level | Peak Current | Servo Voltage | Wire Tension | Duty Cycle |
|---|---|---|---|---|
| 1 | -7.154 | -10.573 | -9.817 | -7.418 |
| 2 | -9.807 | -8.740 | -8.364 | -9.460 |
| 3 | -9.152 | -6.800 | -7.932 | -9.235 |
| Delta | 2.653 | 3.773 | 1.885 | 2.042 |
| Rank | 2 | 1 | 4 | 3 |

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




## V. CONCLUSIONS

In this work, performance parameter (Surface Roughness) 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:

- From the response table it can be clearly seen that the servo voltage has the maximum effect on the surface roughness which is then followed by the peak current, duty cycle and wire tension respectively.
- There is frequent breakage of wire in Run R4 due to high value of current.

## VI. REFERENCES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