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# Optimize of Process Parameters of EN31 on WEDM Machine

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A B S T R A C T

Wire Electrical discharge machining (WEDM) is a non-traditional machining option for manufacturing geometrically intricate shapes or hard material parts that are extremely difficult-to-machine by conventional machining processes. The newer machine technique of machining has been continuously evolving in tool and die making industries, automobiles, aerospace, nuclear, computer and electronics industries to a micro-scale application machining alternative attracting a research interests in this field. In the present work, optimized Kerf Width with the help of analysis performed using Minitab. Initially, DOE (design of experiment) for cutting the EN31 work-pieces are designed and experiments are performed using the same DOE. Thus analysis intends to obtain minimum Kerf Width and Maximum Cutting Speed. The results are analyzed using ANOVA (Analysis of variance) and plots of Kerf Width with varying ON time, varying OFF time and varying Input Current, and further confirmation experiments are performed to validate obtained results to predict optimum values. With the fast developing competitive time in manufacturing industries the immense importance of cutting speed is initial step for machining any work piece. In this line, the similar experimental analysis also performed for obtaining maximum cutting speed and optimized cutting speedfor selected work pieces.

Keywords: WEDM, Non-Traditional Machining, Optimization

## 1. Introduction

Wire Electro Discharge machining (WEDM) is one of the important non-traditional machining processes. WEDM is basically used for machining difficult to machine materials like composites and inter-metallic materials.[1] Wire-cut EDM involves many complex physical and chemical processes including heating and cooling.Wire Electrical Discharge Machining (WEDM) have probably emergedbecause increased use of newer and harder materials like titanium, hardened steel, high strength temperature resistant alloys, fiber-reinforced composites and ceramics in industries like aerospace, nuclear, missile, turbine, automobile, tool and die making industries. WEDM is a different class of modern machining technique. The present demands of the manufacturing industries such as better finish, low tolerance, higher production rate etc. are satisfied by these techniques.[2]

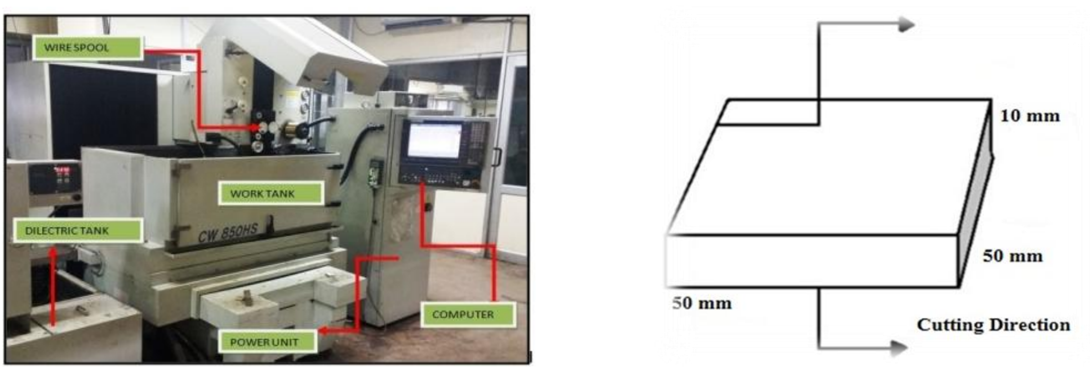
**ShivkantTilekar et al 2014**, [3] have done their work which shows the optimization of response parameters by using ANOVA. The two response parameters are surface roughness and kerf width. Many researchers have done their researches on surface roughness and also on kerf width too. Because both parameters surface roughness and kerf width have crucial importance in Wire-cut EDM. This research work shows the effects of process parameters on kerf width and surface roughness of mild steel and aluminum.**Rupesh *et al* 2013,**[4] developed a multi response optimization procedures using utility method to predict and select various machining parameters in wire electro-discharge machining. **Shyamlal*et al* 2014,**[5]explored the effects of wire electric discharge machining variables on Material removal rate of hybrid metal matrix composite AL7075/SiC/$Al_2O_3$.**Patil et al. [7]** reviewed the recent developments in wire EDM. It reports on the wire EDM research relating to performance measures improvement, process parameters optimization. A wide range of wire EDM industrial applications for the variety of materials is reported with variations. **S V Subrahmanyam et al 2013,**[6]done their work to demonstrate the optimized results of process parameters of Wire Electrical Discharge Machining of a work-piece in his research. For this work the researcher used H13 HOT DIE STEEL as the work-piece. Multiple response of the two parameters Material Removal Rate (MRR) and Surface Roughness (Ra) is observed with the help of Grey-Taguchi Method.**C.D. Shah at el 2013,** have done the study to optimize the output process parameters during machining of Inconnel-600 by Wire cut EDM using response surface methodology (RSM). **Mu-Tian Yan et al 2007,** According to their research they concluded that the fine surface finish can be achieved by some adjustments in power supply. They uses a transistor controlled power supply for their research. **Yi-Ting Liu et al 2009,** represents the development of a high-frequency power supply for surface quality improvement of wire electrical discharge machining (wire-EDM) in their work.**C V S Parameshwara Rao et al 2009,** done research on Wire-cut Electric Discharge Machine (WEDM) for better surface finish and dimensional accuracy. This research evaluates optimal parameters for brass electrodes.

## 2. Design of Experiment

The work of my dissertation is based on machining of metal parts is of EN31 . And as we all know that for every machining process firstly we need the part or work-piece which we want to be machined. So the first step of my dissertation work is to select the work pieces. We took aparts of EN31, on which the machining is done. We took a square parts is of EN31 having sides of 50 mm and 10 mm thick.

**2.1 Machine Employed**

The machine, wire-cut EDM Model CW 850HS developed by CHMER (Ching Hung Machinery and Electric Industries Co. Ltd.) is employed for this dissertation work.




(A) Working zone of WEDM (B) Specimen dimension and cutting path

Fig.1 (A), (B)

**2.2 Machining Parameter and their level**

Taguchi Technique is applied to plan the experiments. Orthogonal arrays were introduced in the 1940s and have been widely used in designing experiments. Based on the machine tool, cutting tool and work piece capability, the process parameters and the level for the three input process parameters were selected and listed in following table.

TABLE 2.3 Machining Parameter and their level

| Sr. No. | Process Parameter | Unit | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| 1 | **ON Time** | **µs** | 2 | 5 | 9 |
| 2 | **OFF Time** | **µs** | 12 | 24 | 36 |
| 3 | **Input Current** | **A** | 1 | 3 | 5 |

**2.3 Design matrix and Observation table for EN31**

The below table is the data collection table EN31of total data having values of Kerf width and cutting speed for every respective cut and their average value.

TABLE 2.4 Experimental Data Collection Table For En31

| ON Time Time(µs) | OFF Time Time(µs) | Input Current A | Wire Feed mm/sec | Machine Time (mm/Sec) | Kerf Width (µM) |
|---|---|---|---|---|---|
| 2 | 12 | 1 | 7 | 2.4735 | 0.2685 |
| 2 | 24 | 3 | 11 | 2.1 | 0.2785 |
| 2 | 36 | 5 | 15 | 1.6305 | 0.29 |
| 5 | 12 | 3 | 15 | 2.61 | 0.27 |
| 5 | 24 | 5 | 7 | 2.2 | 0.29 |
| 5 | 36 | 1 | 11 | 1.79 | 0.3 |
| 9 | 12 | 5 | 11 | 3.7015 | 0.29 |
| 9 | 24 | 1 | 15 | 1.86 | 0.3 |
| 9 | 36 | 3 | 7 | 2.046 | 0.31 |
| Overall Average | | | | 2.267944444 | 0.288555556 |

## 3. Results and Discussion

The cutting speed noted at every cut during the cutting process. And an average value of Kerf Width was measured with the help of profile projector Microscope for every cut after removed the work-piece is being from the machine.Following is the plotted mean effects graph for EN31 obtained by ANOVAwith the help of Minitab19 software

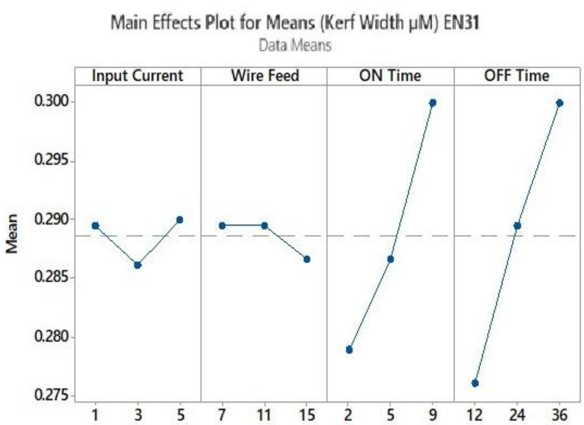



Fig.3.1 Main Effects Plot for Kerf Width of EN31

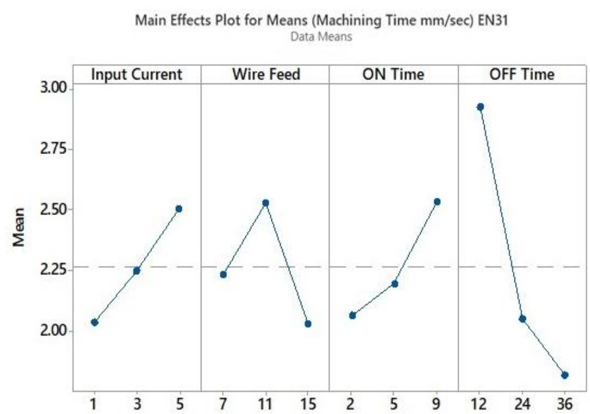



Fig. 3.2 Main Effects Plot for Cutting Speed of EN31

The above graph shows the fluctuation of Kerf width and machine time with four different input parameters on three different levels. This graph is plotted for EN31 work-piece. Three parameters are off time, on time Input current and wire feed raterespectively.

Residual plots are used to evaluate the data for the problems likeNon random variation, non normality, on constant variance, outliers and higher-order relationships, and. It can be seen from Figures 3.3and 3.4 that the residuals follow an approximately straight line in normal probability residuals versus the fitted values. Since residuals exhibit no clear pattern, there is no error due to time or data collection order.

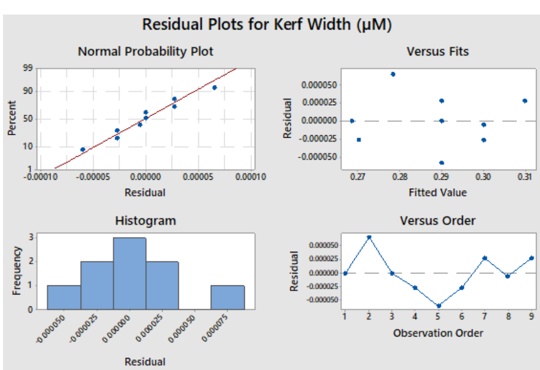



Figure 3.3: Residual Plots for kerf width

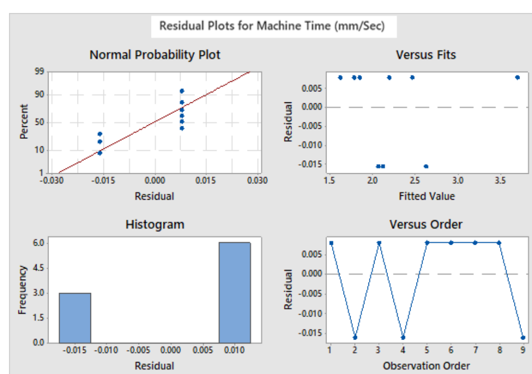



Figure 3.4: Residual Plots for Cutting speed

On the basis of above data obtained from the experiments, graphs were plotted. Then, Minitab 19 software was used for further analysis of experiment. Individual graphs were plotted for Kerf width and Cutting Speed of EN31.

### 3.1 Results Analysis

The wire cut EDM experiments were conducted by using the parametric approach of Taguchi Technique. Using Taguchi Technique, only main effect of individual parameter has been evaluated. The influence of individual wire cut EDM process parameters; on the machining characteristics namely kerf width and Cutting speed have been discussed in this section.

### 3.2 Effect of Process Parameters on the kerf width of EN31

In order to see the influence of process variables on kerf width, experiments were listed in Table 3.1 as per $L_9$ orthogonal array and then output data have been converted into means using MINITAB 19.

TABLE 3.1 Response Table for Means Kr En31

| LEVEL | ON Time | OFF Time | Input Current | Wire feed |
|---|---|---|---|---|
| 1 | 2.041 | 2.068 | 2.928 | 2.24 |
| 2 | 2.252 | 2.2 | 2.053 | 2.531 |
| 3 | 2.511 | 2.536 | 1.822 | 2.034 |
| **DELTA** | 0.47 | 0.468 | 1.106 | 0.497 |
| **RANK** | 3 | 4 | 1 | 2 |

### 3.3 Analysis of Variance of Kerf width

Analysis of Variance was performed for output data of Kerf Width. From Table 6.3, it is clear that Ton (53.63%), Toff (16.52%), Input Current (9.70%) and wire feed (11.23%) have a strong influence on Kerf Width.

Table 3.2 ANOVA for Kerf width Raw Data, Using Adjusted SS for Tests (EN31)

| Source | DF | Adj SS | Adj MS | F-Value | P-Value | Contribution |
|---|---|---|---|---|---|---|
| Model | 7 | 3.09646 | 0.442351 | 386.67 | 0.039 | |
| Linear | 3 | 1.20385 | 0.401284 | 350.77 | 0.039 | |
| ON Time(μs) | 1 | 0.16918 | 0.169176 | 147.88 | 0.052 | 53.63% |
| OFF Time(μs) | 1 | 0.60728 | 0.607275 | 530.83 | 0.028 | 16.52% |
| Input Current (A) | 1 | 0.35678 | 0.356778 | 311.87 | 0.036 | 9.70% |
| wire feed (mm/sec) | 1 | 0.01447 | 0.014472 | 12.65 | 0.174 | 11.23% |
| Error | 1 | 0.00114 | 0.001144 | | | 8.92% |
| Total | 8 | 3.0976 | | | | 100.00% |
| Note : Significant at 95% Level (Value of P <0.05) | | | | | | |

### 3.4 Effect of Process Parameters on the Machining Time of EN31

The response table using Taguchi Analysis method has been used here to calculate the influence of each level of process variable on machining characteristics.

Table 3.3 Response Table for Means MT (EN31)

| LEVEL | ON Time | OFF Time | Current | Wire feed |
|---|---|---|---|---|
| 1 | 0.289 | 0.279 | 0.2762 | 0.289 |
| 2 | 0.286 | 0.286 | 0.289 | 0.289 |
| 3 | 0.29 | 0.3 | 0.3 | 0.286 |
| **DELTA** | 0.0038 | 0.021 | 0.0238 | 0.0028 |
| **RANK** | 3 | 2 | 1 | 4 |

### 3.4 Analysis of Variance of Machine Timing

Analysis of Variance was performed for output data of Cutting Speed. From Table 6.4, it is clear that $T_{on}$ (62.52%), $T_{off}$ (11.70%) and Input Current (9.63%) and wire feed rate (8.28%) have a strong influence on Cutting Speed.

Table 3.4 ANOVA for Cutting Speed Raw Data, Using Adjusted SS for Tests (EN31)

| Source | DF | Adj SS | Adj MS | F-Value | P-Value | Contribution |
|---|---|---|---|---|---|---|
| Model | 7 | 0.001576 | 0.000225 | 20597 | 0.005 | |
| Linear | 4 | 0.001313 | 0.000328 | 30026 | 0.004 | |
| ON Time(μs) | 1 | 0.000448 | 0.000448 | 41006 | 0.003 | 62.52% |
| OFF Time(μs) | 1 | 0.000852 | 0.000852 | 77962 | 0.002 | 11.70% |
| Input Current (A) | 1 | 0.000624 | 0.000542 | 34.31 | 0.108 | 9.63% |
| wire feed (mm/sec) | 1 | 0.000012 | 0.000012 | 1101.8 | 0.019 | 8.28% |
| Error | 1 | 0.00133 | 0.00133 | | | 7.87% |
| Total | 8 | 0.001596 | | | | 100.00% |
| Note : Significant at 95% Level (Value of P <0.05) | | | | | | |

## 4. Confirmation Test

For the validations of obtained result, confirmation experiments were conducted for each of the response characteristics (Kerf Width and Cutting Speed) at optimal levels of the process variables.

Table 4.1 Summarized Predicted and Experimental Values

| **Work Material** | **Response (Units)** | **Optimal Condition** | **Predicted Value** | **Experimental Value** | **$CI_{CE}$** |
|---|---|---|---|---|---|
| **EN31** | Kerf Width (μm) | $T_{on\ 1}$, $T_{off\ 1}$, $IC_2$, $WF_3$ | 1.331 μm | 2.267μm | $0.037 < \mu_{KW} > 2.699$ |
| | Cutting speed (mm/s) | $T_{on\ 1}$, $T_{off\ 3}$, $IC_1$, $WF_3$ | .2076 mm/sec | 0.2885 mm/sec | $1.161 < \mu_{KW} > 1.575$ |

Based on above graphs the results were drawn for optimized Kerf Width of cut and for optimized cutting speed. With the help of graphs the optimized results obtain for both Kerf Width and Machining Time.

## 5. Conclusion

Experimental investigation on wire Electrical Discharge Machining of EN31 has been done using brass wire electrode of 0.25mm dia. The following conclusions are made.Based on the analysis, the optimized input parameter combinations to get the minimum Kerf Width for EN31 work-piece are .3A Input Current, 2μs pulse on time, 12μs pulse off time and Wire Feed rate 15 mm/sec. And Same as 1A Input Current, 2 μs pulse on time, 36 μs pulse off time and Wire Feed rate 15 mm/sec for optimized conditions to get the maximum cutting speed to cut EN31 work-piece.

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