



## Optimization of Process Parameters of Aluminium alloy 8011 in Wire cut Electrical Discharge Machining (WEDM) using Taguchi and ANOVA

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### Abstract

This paper deals with the characteristics of wire cut EDM process of aluminium alloy 8011. The equipment used for the machining is ELECTRONCA ELPULS 50 f Wire cut EDM. Brass wire used as electrode. The dielectric for experiments was De-ionized water. Pulse on time, pulse off-time, current is identified as important parameters which influence the material removal rate (MRR) and surface roughness. Using Taguchi's design of experiments (DOE) were designed for different levels of the factors. The results are obtained from the experiments were analyzed using ANOVA. The factors effect MRR and surface finish were found. Peak current and pulse on time have significant effect on MRR and surface finish.

**Key Words:** Wire electrical discharge machining, Al 8011, MRR, Surface roughness, ANOVA, Taguchi method.

## 1 Introduction

Wire electrical discharge machining (WEDM) is one of the most extended non-conventional machining processes used to produce complex shapes and profiles. It is a thermoelectric process in which work piece material is eroded by a series of discrete sparks between the work piece and a traveling wire electrode immersed in a liquid dielectric medium. These electrical discharges melt and vaporize minute amount of the work material, which is then ejected and flushed away by the dielectric. The movement of the wire is precisely monitored by a computer-numerically controlled (CNC) system. WEDM is widely used in aerospace, automobile, medical, tool and die manufacturing industries. In WEDM process, a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. A thin wire electrode is made of brass or molybdenum having diameter of 0.05-0.30 mm, which is capable of achieving very small corner radii. During the process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire. The most important measures in WEDM are MRR, surface finish, Kerf width, pulse duration, wire feed and voltage are the machining parameters which affects the performance measure. The material is removed by a continuous sparks that are generated between the wire electrode and the work material in the presence of dielectric fluid. The dielectric creates a path for each discharge as the fluid becomes ionized in the gap between tool (wire) and work material. In the place where cutting takes place is heated to extremely high temperature, so that the surface is evaporated and removed. The removed particles are flushed away by the flowing dielectric fluid. The WEDM wire should have high tensile strength and very good electrical conductivity.

Wire electrode :

It exhibits a very small wear ratio. Brass in its pure form is extensively used as an electrode material, when fine finishes are required. Wires used in this machine as the cutting tool. The wire is usually made of brass coated and multi-coated wires are also used.

Dielectric fluid:

Dielectric fluid is a nonconductive liquid that occupies the space be-

tween the work piece and electrode. It acts as an electrical insulator until required space and voltage reached. At that point dielectric fluid ionizes, becoming an electrical conductor and causes the current or spark to flow to the work piece.

Selection of material :

The type of material selected is Aluminium which has very high tensile strength, light in weight, corrosion resistance and the ability to withstand extreme temperatures. Aluminium is easily machined, cast, drawn and extruded on the other hand Machining Aluminium alloy using conventional machining methods has difficulties such as high cutting temperature and high tool wear ratio.



Fig 1: Wire cut EDM Machine

Table 1: Chemical composition

| Al    | Si   | Fe   | Cu   | Mg   | Mn   |
|-------|------|------|------|------|------|
| 89.45 | 0.29 | 0.23 | 0.04 | 0.09 | 0.06 |

Table 2 : Mechanical Properties of Al 8011

| S.NO | Properties               | Value /Units          |
|------|--------------------------|-----------------------|
| 1    | Density                  | 2.78g/cm <sup>3</sup> |
| 2    | Melting point            | 650 °C                |
| 3    | Atomic weight            | 26.98 g/mol           |
| 4    | Coefficient of expansion | 23.4/ ° C             |
| 5    | Modulus of elasticity    | 68.6 Gpa              |
| 6    | Boiling point            | 2470 °C               |

Table 3 : Parameters and range

| S.No | Parameters | Range         |
|------|------------|---------------|
| 1    | Pulse on   | 33-37 $\mu$ s |
| 2    | Pulse off  | 7-9 $\mu$ s   |
| 3    | Current    | 2-4 A         |

## 2 EXPERIMENTAL PROCESSES

The ELECTRONCA ELPULS 50 f Wire cut EDM was used to carry out the experiments. The Al8011 has been applied as work piece material for the experiments. The shape was machined by WEDM with 10 mm x 6 mm x 6 mm size. Wire electrode were used namely Brass wire. Deionized water was selected as the dielectric for experiments.

Table 4: List of experiments conducted

| S.No | Pulse on ( $\mu$ s) | Pulse off ( $\mu$ s) | Current (A) |
|------|---------------------|----------------------|-------------|
| 1    | 33                  | 7                    | 2           |
| 2    | 35                  | 8                    | 2           |
| 3    | 37                  | 9                    | 2           |
| 4    | 33                  | 8                    | 3           |
| 5    | 35                  | 9                    | 3           |
| 6    | 37                  | 7                    | 3           |
| 7    | 33                  | 9                    | 4           |
| 8    | 35                  | 7                    | 4           |
| 9    | 37                  | 8                    | 4           |

Table 5: MRR Calculation

| Experiment No. | MRR  | S/N Ratio |
|----------------|------|-----------|
| 1              | 4.69 | 3.563     |
| 2              | 4.85 | 3.403     |

|   |       |        |
|---|-------|--------|
| 3 | 4.67  | 2.334  |
| 4 | 9.57  | 8.986  |
| 5 | 8.71  | 8.448  |
| 6 | 11.18 | 10.203 |
| 7 | 11.00 | 11.974 |
| 8 | 14.17 | 10.174 |
| 9 | 12.48 | 11.395 |

### 3 RESULT AND DISCUSSION

Nine experiments were conducted using Taguchi (L9) orthogonal array experimental design methodology and there are two tests for each experiment to obtain S/N values. The results from the experiments are collected for material removal rate and surface roughness. In the present study all the designs, plots and analysis have been carried out using Minitab17 statistical software. Larger material removal rate and lower amount of surface roughness show the high productivity of Wire EDM. Therefore, large the better and small the better are applied to calculate the S/N ratio of cutting speed and surface roughness, respectively.

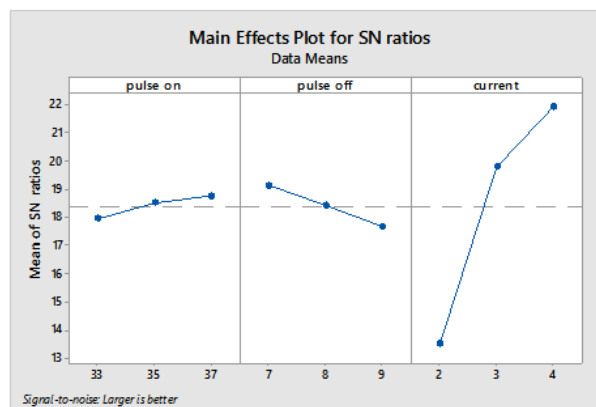


Fig 2: Effect of processes parameters on MRR S/N ratio (Brass wire )

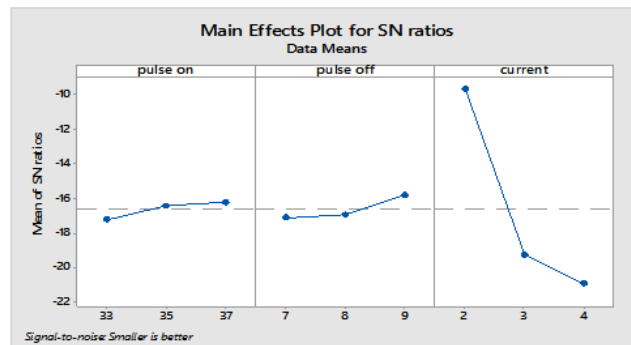


Fig 3: Effect of processes parameters on Surface roughness S/N ratio (Brass wire )

Table 6: Response Table for Signal to Noise Ratios Larger is better

| Level | Pulse ON | Pulse OFF | Current |
|-------|----------|-----------|---------|
| 1     | 17.96    | 19.14     | 13.51   |
| 2     | 18.51    | 18.42     | 19.80   |
| 3     | 18.06    | 17.62     | 21.93   |
| Delta | 0.80     | 1.47      | 8.42    |
| Rank  | 3        | 2         | 1       |

Table 7: Analysis of Variance(ANOVA)

| Source      | DF | Adj.SS  | Adj MS  | F-Value | P-Value |
|-------------|----|---------|---------|---------|---------|
| Pulse ON    | 2  | 1.136   | 0.5681  | 0.41    | 0.710   |
| Pulse – OFF | 2  | 0.276   | 0.1379  | 0.10    | 0.910   |
| Current     | 2  | 106.53  | 53.2694 | 38.24   | 0.025   |
| Error       | 2  | 2.786   | 1.3932  | --      | -       |
| Total       | 8  | 110.737 | --      | -       | -       |

Table 8 : Response Table for Signal to Noise Ratios Smaller is better

| Level | Pulse ON | Pulse OFF | Current |
|-------|----------|-----------|---------|
| 1     | -17.224  | -17.120   | -9.679  |
| 2     | -16.441  | -16.948   | -19.260 |
| 3     | -16.224  | -15.821   | -20.950 |
| Delta | 1.001    | 1.300     | 11.271  |
| Rank  | 3        | 2         | 1       |

Table 9: Analysis of Variance

| Source     | DF | Adj.SS  | Adj MS  | F-Value | P-Value |
|------------|----|---------|---------|---------|---------|
| Pulse ON   | 2  | 1.765   | 0.8825  | 1.65    | 0.377   |
| Pulse –OFF | 2  | 5.361   | 2.6803  | 5.01    | 0.166   |
| Current    | 2  | 94.341  | 47.1707 | 88.19   | 0.011   |
| Error      | 2  | 1.070   | 0.5349  | --      | -       |
| Total      | 8  | 102.537 | --      | -       | -       |

## 4 CONCLUSION

Based on the experimental results and analysis, experiments results of WEDM of tungsten Carbide indicate peak current and pulse on have significant effect on MRR and surface roughness. ANOVA analysis shows that the most influencing parameter is the current for both MRR as well as the surface roughness. Variation of this process parameter cause big change in the MRR and surface roughness. The optimal combination of process parameters for obtaining maximum MRR through Taguchi method for machining aluminium 8011 using EDM ,Peak current- 4amps , Pulse on time-37 sec, Pulse off time - 9 sec. The optimal combination of process parameters for obtaining minimum surface roughness through Taguchi method for machining aluminium 8011 using EDM ,Peak current-2 amps, Pulse on time- 33 sec, Pulse off time - 7sec.

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