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INVESTIGATION OF MACHINING CHARACTERISTICS OF ALUMINIUM 8011 BY WIRE CUT EDM PROCESS

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ABSTRACT

This study deals with the machining characteristics of wire-cut EDM process in aluminium alloy 8011, the equipment used for machining is EZEECUT PLUS Wire cut EDM. Brass wires are used as electrode in the combination of two non ferrous metals, alloyed in between the range 63%–65% copper and 35%–37% zinc. The dielectric for experiments was De-ionized water.

Current, pulse–on and pulse-off is identified as important parameters which has influence on material removal rate (MRR) and surface finish. Using Taguchi's DoE experiments were designed for different working levels of the factors. The results obtained from the experiments were analysed using ANOVA and the factors affect MRR and surface finish were found. Using Taguchi's method we have identified the optimum process parameters for machining Aluminium 8011. Peak current and pulse-on have significant effect on MRR and surface finish.

Keywords: Wirecut Electrical Discharge machining, Aluminium 8011, Metal Removal Rate, Surface roughness, Analysis of variance, Taguchi methods.

INTRODUCTION

Electrical discharge machining (EDM) is a non-conventional machining process which is widely used to produce dies and moulds in metalworking industries. This technique has been developed in the late 1940s and has been one of the fast increasing methods in developed areaduring 1980s and 1990s.

This machining of hard metals that are impossible to machine using conventional machining method or machines are done by this method. It is widely used, especially for cutting convoluted contours or cavities that also would be tough to produce with

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conventional machining methods. EDM is suitable for only materials which are electrically conductive. Metal that can be machined by using EDM include nickel-based alloy such as aerospace material, very hard tool steels etc. The main concept of WEDM is shown in Figure 1. In this process, a moving wire passes through a recommended path and removes material from the workpiece. WEDM method is basically an electro-thermal mechanism to cut the material. The material is removed by a continuous sparks that are generated between the wire electrode and the work material in the presence of (dielectric) distilled water. 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 wires materials for WEDM are made of tungsten, copper, brass, etc. (0.02 – 0.3 mm in diameter), which are capable to achieve very small corner radii. The WEDM wire should have high tensile strength and very good electrical conductivity.

The melting temperature is the only factor of the parts to be machined rather than strength or hardness. Electrical energy is used to generate a channel of plasma between the cathode and anode , and turns it into thermal energy at a temperature in the range of 8000–12,000°C or maximum 20,000°C initializing a substantial amount of heating and melting of material on the surface of each pole. When the pulsating direct current power supply occurring between 20,000 and 30,000 Hz is turned off, the plasma channel breaks down. Hence the present article objective is to study experimental investigation and machining characteristic of WEDM on aluminium 8011 and to analyse the effect of input parameter of WEDM in aluminium 8011 material.

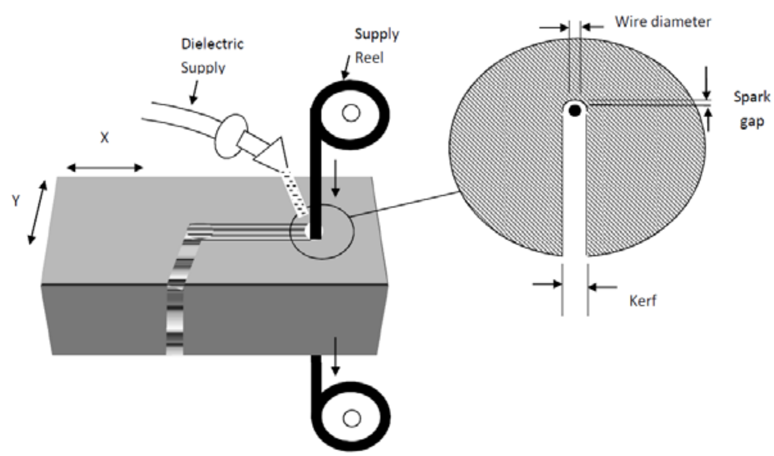

Fig. 1: Wire cut EDM

Wire electrodes

Wires used in this machine as the cutting tool. The wire is usually made of brass, copper, or tungsten, zinc or brass coated and multi-coated wires are also used. copper or brass in its pure form is extensively used as an electrode material, when fine finishes are required. It exhibits a very small wear ratio. A major problem with copper is its poor machinability.

The properties required for the wire electrode are:

(a) Electrical properties

(b) Geometrical properties

(c) Physical properties

(d) Mechanical properties

Electrical discharge performance is required for steady and elevated energy discharge for high-speed cutting. The electrical properties are articulated by its electrical resistance. To minimize Energy two current contacts are used and selecting high-conductivity electrode materials, such as aluminium, brass, copper and its alloys, with optimized settings. Conductivity determines how readily the energy is transferred from power feed to the actual point of cutting. For faster cutting the surface area of the wire should be increased. The wires diameter is typically about 0.3mm for rough cuts and 0.2mm for finishing cuts. The wire should have sufficient tensile strength, fracture toughness, high electrical conductivity and capacity to flush away the debris produced during cutting.

Dielectric fluid

Dielectric fluid is a nonconductive liquid that occupies the space between the work piece and electrode. It act as an electrical insulator until required space and voltage reached. At that point dielectric fluid ionizes, becoming an electrical conductor and cause the current or spark to flow to the work piece.

The main functions of the dielectric fluid are:

- To flush the eroded metal particles produced during machining from the discharge gap and remove the particles from the oil to pass through a filter system.
- To provide insulation for the gap between the electrode and the work piece.
- To dissipate the heat at a section that was heated by the discharge machining.

Selection of material

Aluminium is a chemical element in the boron group with symbol **Al** and atomic number 13. It is a silvery-white, soft, non-magnetic, ductile metal. Aluminium is the third most abundant element in the earth's crust after oxygen and silicon.

Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to phenomenon of passivation. Structural components made from aluminium and its alloy is vital to the aerospace industry. The yield strength of pure aluminium is 7-11 Mpa, while aluminium alloys have yield strength ranging from 200 Mpa to 600 Mpa.

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. So Aluminium alloy is classified as difficult-to-machine materials.

Aluminium alloy are used in many different industries such as automobile, aerospace, Cutting Tools. On the other hand, there is some advantages for aluminium alloy use because of its low cost, availability, and manufacturability.

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.

The Chemical composition, Mechanical properties and Material properties are presented in Table 1 to 3.

Table 1: Chemical composition of aluminum 8011 alloy

Al	Si	Fe	Cu	Mg	Mn
89.50	0.296	0.236	0.043	0.093	0.064

Table 2: Mechanical properties of aluminium

Density	2.6898 g/cm^3
Melting point	660^{o}C
Boiling point	2480^{o}C
Coefficient of expansion	23.5/^{o}C
Atomic weight	26.98 g/mol
Modulus of elasticity	68.3 GPa

Table 3: Material properties of aluminium

Young's Modulus (GPa)	Shear Modulus (GPa)	Bulk modulus (GPa)
70	26	76

Selection of wire electrode

Brass wires are the combination of copper and zinc, alloyed in the range 63%–65% copper and 35%–37% zinc. Machining speed is proportional to the presence of zinc in the EDM wire electrode owing to stable discharge during machining. The zinc in the brass wire actually boils off, or vaporizes, which helps in cooling the wire and delivers more usable energy to the work zone. The addition of zinc in the wire gives a higher tensile strength, lower melting point, higher vapor pressure rating and improved flushability, but its conductivity is significantly reduced. Machining speed can be further enhanced with the addition of more zinc (more than 40%) to the wire, but in that case the drawing process to form a wire becomes difficult because of the presence of a brittle phase in the alloy

The processing speed and the accuracy of the cut surface of the work piece are improved, and the number of failures owing to breaking of the cutting wire is reduced. Brass wire are particularly suited for making small parts with very tight tolerances and good surface finishes.

Exeriment using taguchi method

Number of experiments was determined using the Taguchi method. The Taguchi method is a simple, powerful and efficient Design of Experiments technique, which can be used to improve process performance by conducting minimum number of experiments. It leads to reduction in rework costs, manufacturing and cycle time costs in processes. The Taguchi design is to find optimal values of the process parameters in manufacturing processes. Compared to traditional experimental designs, the Taguchi method makes use of a special design of orthogonal arrays to examine the quality characteristics through a minimal number of experiments. The experimental results are then transformed into S/N ratios to evaluate the performance characteristics. Therefore, the Taguchi method concentrates on the effects of variations on quality characteristics, rather than on the averages. That is, the Taguchi method makes the process performance insensitive to the variations of uncontrollable noise factors. The optimum parameter conditions are then determined by performing the parameter design.

The general steps involved in the Taguchi Method are as follows:

1. Define the process objective or more specifically, a target value for a performance measure of the process. The target of a process may be either minimum or maximum.
2. Determine the design parameters that are affecting the process. Parameters are the variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled. The number of levels of each parameters must be specified. Increasing the number of levels leads to increase the number of experiments to be conducted.
3. Identify suitable orthogonal array for the parameter design indicating the number of and conditions for each experiment.
4. Conduct the experiments following the various factors and levels in the orthogonal array to collect data on the effect on the performance measure.
5. Complete data analysis by S/N Ratio and ANOVA to determine the effect of the different parameters on the performance measure.
6. The parameters which are affecting a process that can be controlled have been determined, the levels at which these parameters should be varied must be determined.
7. Determining the optimum levels of a variable to test requires an in-depth understanding of the process, including the minimum, maximum, and current value of the parameter.
8. If the difference between the minimum and maximum value of a parameter is large, the values being tested can be further apart or more values can be tested. If the range of a parameter is small, then less value can be tested or the values tested can be closer together.

Table 4: Orthogonal array of Taguchi method

Experiments	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2

Cont…

Experiments	P1	P2	P3
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 5: Parameters and its range

Parameters	Range of parameters
Current	1-3 A
Pulse ON	32-36 µs
Pulse OFF	6-8 µs

Table 6: Factors and levels

Parameters	Range of parameters
Current	1-3 A
Pulse ON	32-36 µs
Pulse OFF	6-8 µs

EXPERIMENTAL

The Ezeecut Plus Wire cut EDM was used to carry out the experiments. The Ezeecut Plus 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. De-ionized water was selected as the dielectric for experiments, as that is the standard for Wire EDM

Table 7: List of experiment conducted

Experiment No.	Current (A)	Pulse ON (µs)	Pulse OFF (µs)
1	1	32	6
2	1	34	7

Cont…

Experiment No.	Current (A)	Pulse ON (μs)	Pulse OFF (μs)
3	1	36	8
4	2	32	7
5	2	34	8
6	2	36	6
7	3	32	8
8	3	34	6
9	3	36	7

Table 8: MRR Calculation table

Experiment No.	MRR (mm^3/min) for brass	S/N Ratio for brass
1	3.69	3.4631
2	3.85	3.3031
3	3.67	2.2347
4	8.57	8.8868
5	7.71	8.3438
6	10.18	10.1035
7	10.00	10.9749
8	13.17	9.1743
9	11.48	10.3955

RESULTS AND DISCUSSION

The results from the experiments are collected for material removal rate and surface roughness. 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. In the present study all the designs, plots and analysis have been carried out using Minitab 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.

1. Larger the Better:

$$(S/N)_{HB} = -10 \text{Log} (MSD_{HB})$$

Where: $MSD_{HB} = 1/R \sum_{i=1}^{R} (yi^2)$

2. Smaller the Better:

$$(S/N)_{LB} = -10 \text{ Log } (MSD_{LB}) = 1/R \sum_{i=1}^{R} (yi^2)$$

Table 8: ANOVA analysis for material removal rate using brass wire

Source	DoF	Sum of squares (SS_A)	Variance (V_A)	FAo	P	Contribution (%)
Current	2	1.9107	0.9554	127.25	0.008	86.4699
Pulse on	2	0.0819	0.0409	5.45	0.155	3.4275
Pulse off	2	0.0508	0.0254	3.38	0.228	3.6324
Error	2	0.015	0.0075	-	-	6.4699
Total	8	2.0539	-	-	-	100

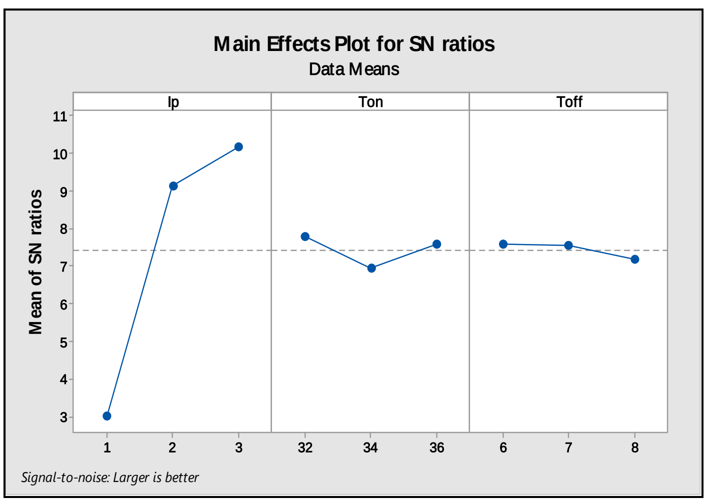

Fig. 2: Effect of significant parameters on MRR S/N Ratio (Brass wire electrode)

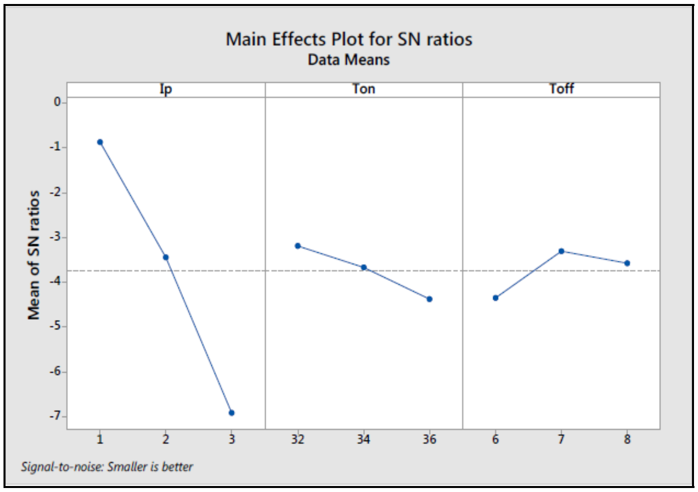

Fig- 3 Effect of Significant Parameters on Surface Roughness S/N Ratio (Brass wire Electrode)

Table 8: ANOVA analysis for surface roughness using Brass wire

Source	Dof (f)	Sum of squares (SS_A)	Variance (V_A)	FAo	P	Contribution (%)
Current	2	94.341	47.1707	88.19	0.011	89.16
Pulse on	2	1.765	0.8825	1.65	0.377	7.16
Pulse off	2	5.361	2.6803	5.01	0.166	0.8148
Error	2	1.070	0.5349	-	-	2.85
Total	8	102.537	-	-	-	100

S = 0.731353 R-Sq. = 98.96% R-Sq. (adj) =95.83%

S = 0.178931 R-Sq. = 99.27% R-Sq. (adj) = 97.08%

CONCLUSION

In this study, the influence of brass wire on the performance of WEDM is compared with molybdenum wire. And, the effect of process parameters on the process performance was determined by performing experiments under different machining conditions. Based on the experimental results and analysis, the following conclusions can be drawn:

Experiments results of WEDM of tungsten Carbide indicate peak current and pulse on have significant effect on MRR and surface roughness.

Analysis using Taguchi method shows that the optimized values of current pulse on and pulse off for MRR is 3,36,6 respectively and for surface roughness is 1,32,6. 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.

Compared with brass wire, molybdenum wire which results smoother surface finish and the material removal rate is also more.

The optimal combination of process parameters for obtaining maximum MRR through Taguchi method for machining aluminium 8011 using EDM is given below:

Peak current- 3amps

Pulse on time-36 µsec

Pulse off time - 7 µsec

The optimal combination of process parameters for obtaining minimum surface roughness through Taguchi method for machining aluminium 8011 using EDM is given below:

Peak current-1 amps

Pulse on time- 32 µsec

Pulse off time - 6µsec

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