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An Experimental Study of Surface Roughness and Material Removal Rate on *Wire Edm* with *Aluiminium Alloy 8011*

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ABSTRACT

Wire EDM machining process is one of the most widely used machining processes and machined surfaces are widely employed while assembling with other parts. Surface finish is an important measure as it may improve frictional resistance, fatigue strength or creep life. Surface roughness also affects several functional attributes such as heat transmission, ability to hold lubricant, surface friction, wearing etc. It is hard to achieve good surface quality without the proper selection and control of the process parameters. In the present day world, it is essential to consider economy in addition to quality in any machining operation. Material removal rate (MRR) is one among them and is related to the quantity of material removal per unit time. The higher value of MRR reduces the machining time and finally productivity of the system increases. Thus surface roughness and MRR are most-specified customer requirements in a machining process.

The selection of optimal cutting parameters is of great concern in the manufacturing industry, where the economy of machining operation plays a key role in the competitive market. Earlier, several efforts have been made to optimize the machining parameters and MRR. While unconventional machining has received relatively little attention with regard to the optimization of cutting parameters.

In this work, Wire EDM machining was performed to experimental values of the surface roughness and MRR of 8011 aluminum alloy with brass coated wire under wet conditions is found.

KEYWORDS: Surface Roughness, Material Removal Rate, Wire EDM, Aluminum 8011

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1. INTRODUCTION

1.1 Introduction to 8011 Aluminum Alloy

In the present study on unconventional machining process, the work piece material under consideration is 8011 aluminum alloy. 8011 aluminum alloy has excellent surface properties, such as weld ability, corrosion resistance and so on. Thus, we can cut 8011 aluminum plate into different shapes according to our actual uses. Strength-and-weight ratio: lightweight is an obvious advantage of 8011 aluminum sheet compare with copper, iron and other metals.

8011 is highly weld able, for example using tungsten inert gas welding (TIG) or metal inert gas welding (MIG). Typically, after welding, the properties near the weld are those of 8011-O, a loss of strength of around 80%. The material can be re-heat-treated to restore -T4 or -T6 temper for the whole piece. After welding, the material can naturally age and restore some of its strength as well. 8011 is an alloy used in the production of extrusions-long constant-cross-section structural shapes produced by pushing metal through a shaped die. 8011 is an alloy that is suitable for hot forging. The billet is heated through an induction furnace and forged using a closed die process. Automotive parts, ATV parts, and industrial parts are just some of the uses as a forging.

The chemical composition of 8011 aluminum alloy (wt. %) is shown in **Table 1.**

Table 1-Chemical composition of 8011 aluminum alloy

Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
95.8 -98.6	0.04 -0.35	0.1 -0.2	0.6 - 0.9	0.01-0.10	0.01-0.10	0.6 -0.95	0.02-0.03	0.01-0.2

1.2. Types of EDM machining

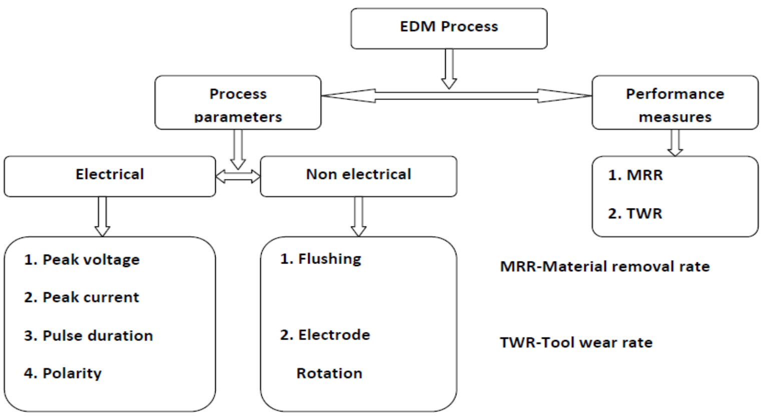

Figure 1- Process Parameters and Performance Measure of EDM Process

EDM uses thermal erosion to remove small bits of conductive metal using repeated electrical discharges between the cutting tool, which functions as the electrode, and the piece itself in the presence of a dielectric fluid. The voltage discharge occurs in the gap between the cutting tool and the piece, and the heat essentially vaporizes small amounts of the metal, which are washed away in a continuous stream of the dielectric fluid. The temperature during EDM processing can reach as high as 15,000 degrees Fahrenheit, and can change the metallurgy of materials. When metallurgical changes occur, the area is referred to as the "recast" layer. The recast layer can be easily removed with various methods. While all EDM uses an electrical current to cut material, there are several types of EDM that may be used in a specific instance to achieve required results. EDM methods fall into two major categories, wire and ram. Ram/Sinker EDM has several sub-categories of its own. The best EDM method for a part depends on the material and machined shapes required. The quality of the surface finish in Wire EDM operations has been related to method of cutting, diameter of wire, pulse on time, spark gap voltage, peak current, pulse of time. Proper selection of some of these factors is probably the most difficult thing for the machinist due to so many variables.

1.3 Surface Roughness

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough, if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application. The surface characteristics of a component are shown in **Figure 2**

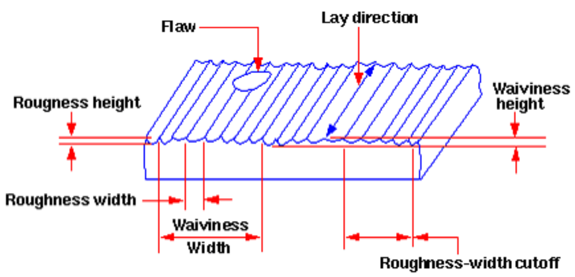

Figure: 2- Surface characteristics

1.4 Surface Roughness Measuring Instrument

The instrument used for measuring surface finish was surface indicator. This device consists of tracer head and amplifier. The head housed a diamond stylus, having a point radius of 0.03mm, which has been pressed lightly against the surface of the work and may be moved by hand. Any movement of the stylus covered by surface irregularities is converted into electric fluctuations by the tracer head. These signals are magnified by the amplifier and registered on the digital display. The rating shown on the display indicates the average height of the surface roughness or the depth of the surface from the reference line. For accurate determination of the surface finish the indicator must first be calibrated by setting it to a precision reference surface on a block calibrated to ASA standards. The surface roughness was measured by using a portable surface roughness tester (mitutoyo surf test SJ-210). An average of three measurements was used as a response value in each machined slot.

1.5 Material Removal Rate

During the experimentation on end milling operation, the MRR is obtained by weighing the weight of work piece before and after milling process and then subtracting the weight after milling from weight before milling. Then the difference in weights is divided by the time measured of the material removal process. Thus the MRR is given by the formula:

$$\text{MRR} = \left(\frac{Area*Depth\ of\ cut}{Time}\right)\frac{mm^3}{min}.$$

Where Area = l*b (mm²)

L = length of cut (mm)

b = width of cut (mm)

d = depth of cut (mm)

t = time taken for machining (minutes)

It is observed that, there is less emphasis in literature on Wire EDM operation in find Surface Roughness and Material Removal Rate. So in the present work, an attempt is made to study the effect of various machining parameters like Voltage ,Pulse on time and depth of cut in Wire EDM of 8011 aluminum alloy with surface roughness and material removal rate (MRR) as response parameters. The study is conducted under wet conditions (i.e., with coolant) with Brass Coated wire as cutting tool.

2. METHODOLOGY

Unconventional machining is one of the most widely used machining processes and machined surfaces are widely employed while assembling with other parts. In this work we selected the Wire cut Electrical Discharge Machining (WEDM).

Wire electrical discharge machining (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profiles. It is considered as a unique adaptation of the conventional EDM process, which uses an electrode to initialize the sparking process. However, WEDM utilizes a continuously traveling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.3 mm, which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. The Principle and Machining Process of Wire EDM is shown in **Figure 2.1 and 2.2**

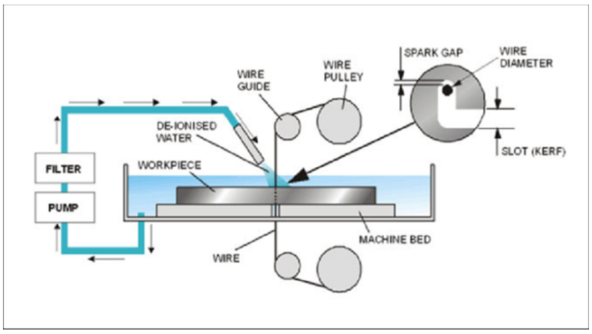

Figure 3- Principle of WEDM

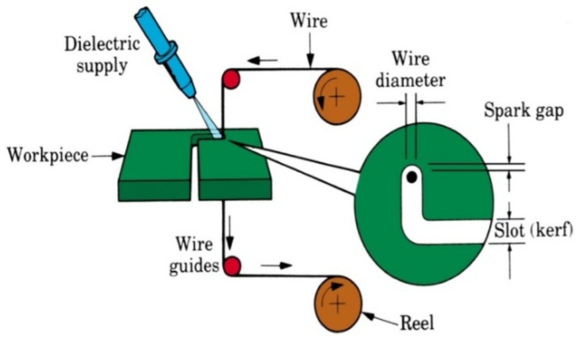

Figure 4- Machining process

2.1 CNC Wire EDM Machine

The CNC WIRE EDM machine used in the present study is shown in **Figure 3**. The standard control features of the machine are:

- Manual data input
- Simultaneously controllable three axes
- Part programming storage and editing
- Automatic tool changer
- Absolute / Incremental programming

The machine used for the WIRE EDM tests is a Enova CNC V5 wire EDM center with 7.5 kW driver motor. For generating the required surfaces, CNC part programs for tool paths were created with specific commands. The experimentation was carried out with brass coated copper wire arrangement and the die electric fluid is used as coolant and the die electric fluid is mostly water showing the arrangement in the **Figure 4**. The Specifications of Wire EDM is shown in **Table 2.**

Figure 5- CNC Vertical Wire EDM Machine

Figure 6- Wire EDM Machining

Table 2-Specifications of CNC Wire EDM machine

PARAMETER	DESCRIPTION
MODEL	Enova CNC V5
SOFTWARE	EU-CAM
MAIN AXES TRAVELS (X,Y)	385 X 287 MM
U X V	100 X 100
WORK TABLE SIZE	680 X 500 MM
MAX. TAPER ANGLE	35°/ 50 MM
MAX. WORK PIECE HEIGHT	300 MM
MAX. WORK PIECE WEIGHT	500 kg
RESOLUTION	0.0005 MM
MAX. WIRE SPOOL CAPACITY	8 kg

3. EXPERIMENTATION ON WIRE EDM PROCESS OF 8011 ALUMINUM ALLOY

The details of experimentation conditions, measurements and the procedure adopted for the study are described in this section.

3.1 Design of Experiment

The design of experiments technique is an important tool, which permits us to carry out the modeling and analysis of the influence of process variables on the response variable. The response variable is an unknown function of the process variables, which are known as design factors. There are a large number of parameters that can be considered for machining of a particular material in Wire EDM machining.

In the present study, the most widely used machining parameters such as pulse on time, pulse of time, spark gap voltage and depth of cut are considered as design factors. The range of values of each factor was set at three different levels as shown in **Table 2**. A full factorial design is used to design factors so that all the interactions between the response variable and process variables can be investigated. The Experimental Procedure using surface roughness tester is shown in **Figure 7 and 8**

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Table 2 "Process variables used in the experimentation"

S.no	Parameter	Symbol	Level 1	Level 2	Level 3
1	Pulse on time	Ton	8	10	12
2	Depth of cut	D	0.5	0.6	0.7
3	Spark gap voltage	V	5	10	15

Figure 7 R_a measurement by using surface roughness tester

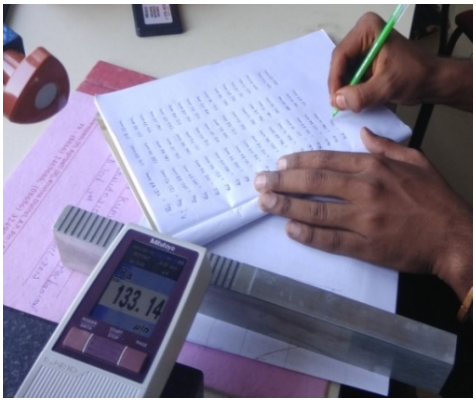
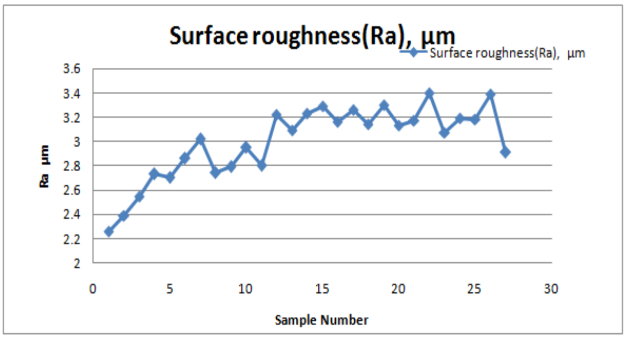


Figure 8 Readings noting while the tester on specimen

3.2 Experimental Data

Experimental data of R_a value and MRR corresponding to 27 designs of experiments has been tabulated and given in **Table 3** for machining Wire EDM with coolant. The experimental values of R_a and MRR under varying machining conditions shown in **Figure 9.**



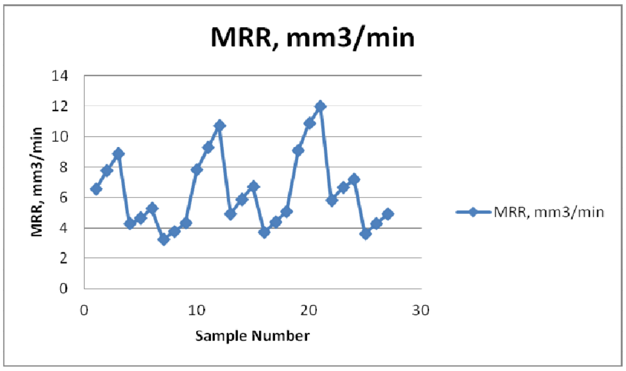


Figure 9 The experimental values of R_a and MRR under varying machining conditions

Table 3 "Experimental data for machining with Brass Coated wire with coolant"

S. No.	Pulse on time (Ton)	Voltage (V) volts	Doc (d), mm	Surface roughness(Ra), µm	MRR, mm^3/min
1	8	5	0.5	2.26	6.545
2	8	5	0.6	2.39	7.770
3	8	5	0.7	2.55	8.873
4	8	10	0.5	2.73	4.285
5	8	10	0.6	2.70	4.645
6	8	10	0.7	2.86	5.316
7	8	15	0.5	3.02	3.231
8	8	15	0.6	2.74	3.789
9	8	15	0.7	2.79	4.367
10	10	5	0.5	2.95	7.826
11	10	5	0.6	2.80	9.310
12	10	5	0.7	3.22	10.723
13	10	10	0.5	3.09	4.931
14	10	10	0.6	3.23	5.885
15	10	10	0.7	3.29	6.720
16	10	15	0.5	3.16	3.711
17	10	15	0.6	3.26	4.426
18	10	15	0.7	3.14	5.101
19	12	5	0.5	3.30	9.090
20	12	5	0.6	3.13	10.854
21	12	5	0.7	3.17	12
22	12	10	0.5	3.40	5.844
23	12	10	0.6	3.07	6.646
24	12	10	0.7	3.19	7.20
25	12	15	0.5	3.18	3.60
26	12	15	0.6	3.39	4.294
27	12	15	0.7	2.91	4.941

4. RESULTS AND DISCUSSION

Once the influences of Pulse on time, Voltage and Depth of cut on response parameters (R_a and MRR) have been assessed.

4.1 Variations of response parameters with respect to machining parameters

Figure 10 shows the effect of depth of cut at the selected levels of voltages on surface roughness and MRR. It is adjusted by taking all measured values with the same pulse on time at 8 sec for particular depth of cut. The Observations are given in **Table-4.**

Figure 11 shows the effect of depth of cut at the selected levels of voltages on surface roughness and MRR. It is adjusted by taking all measured values with the same pulse on time at 10 sec for particular depth of cut. The Observations are given in **Table 5.**

Figure 12 shows the effect of depth of cut at the selected levels of voltages on surface roughness MRR. It is adjusted by taking all measured values with the same pulse on time at 12 sec for particular depth of cut. The Observations are given in **Table 6.**

Table 4 "Observations on Variation of R_a and MRR with Depth of Cut at Pulse on time =8 Sec"

Voltage	Observation on Surface Roughness	Observation on MRR
5V	the surface roughness value increases at different	the MRR value increases at different depth of cuts
10V	the surface roughness value increases and decreases again increases at different depth of cuts i.e. 0.5-	the MRR value increases at different depth of cuts increases i.e. 0.5-0.7mm
15V	the surface roughness value increases and decreases then again increases at different depth of cuts i.e.	the MRR value increases at different depth of cuts increases i.e. 0.5-0.7mm

Table 5 "Observations on Variation of R_a and MRR with Depth of Cut at Pulse on time =10 Sec"

Voltage	Observation on Surface Roughness	Observation on MRR
5V	the surface roughness value increases at different	the MRR value increases at different depth of cuts
10V	the surface roughness value increases at different	the MRR value increases at different depth of cuts
15V	the surface roughness value increases and decreases then again increases at different depth of	the MRR value increases at different depth of cuts increases i.e. 0.5-0.7mm

Table 6 "Observations on Variation of R_a and MRR with Depth of Cut at Pulse on time =12 Sec"

Voltage	Observation on Surface Roughness	Observation on MRR
5V	the surface roughness value increases and decreases then again increases at different depth of cuts i.e. 0.5-0.7mm	the MRR value increases at different depth of cuts increases i.e. 0.5-0.7mm
10V	the surface roughness value increases and decreases then increases at different depth of cuts i.e. 0.5-0.7mm	the MRR value increases at different depth of cuts increases i.e. 0.5-0.7mm
15V	the surface roughness value increases and decreases at third point of different depth of cuts i.e. 0.5-0.7mm	the MRR value increases at different depth of cuts increases i.e. 0.5-0.7mm

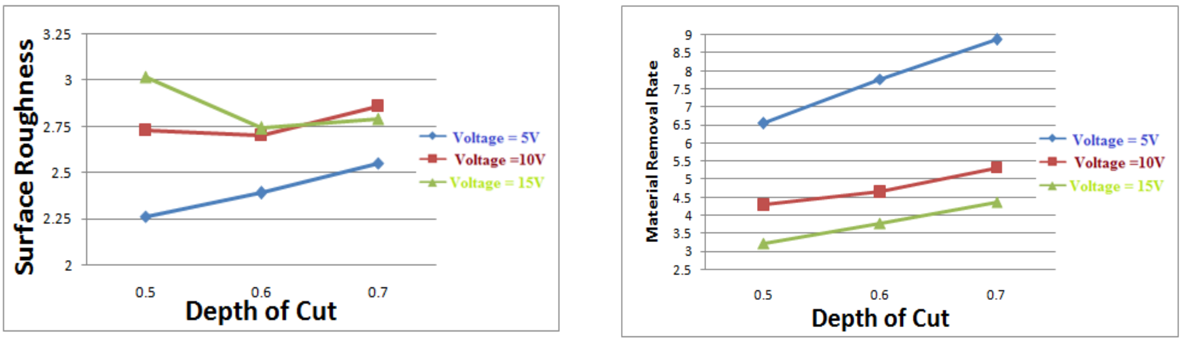


Figure 10 Variation of R_a and MRR with Depth of Cut at Pulse on time =8 Sec

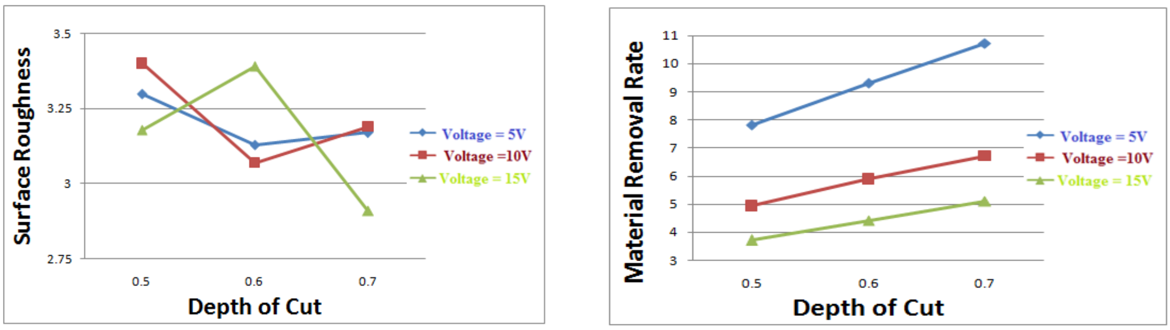


Figure 11 Variation of R_a and MRR with Depth of Cut at Pulse on time =10 Sec

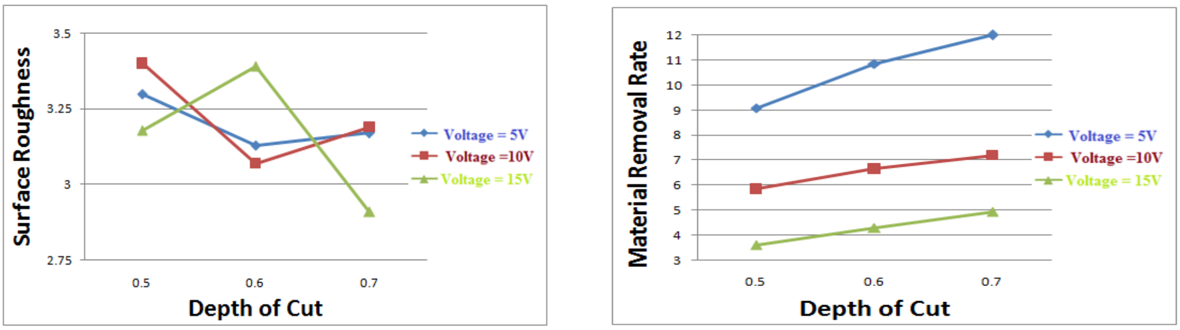


Figure 12 Variation of R_a and MRR with Depth of Cut at Pulse on time =12 Sec

5. CONCLUSIONS

This project presented Operation of Wire EDM for finding surface roughness and MRR with Voltage, Depth of Cut, and Pulse on time as machining Parameters. The process is done for 8011 aluminum alloy when the machining is done with coolant using Brass coated wire.

Actually the surface roughness increases with the increase in Voltage and decreases with increase in Pulse on time, whereas the effect of depth of cut is not regular. It is also found that, the Voltage and depth of cut are both dominant parameters with respect to the MRR. The MRR increases with increase in Voltage and also depth of cut, but the effect of pulse on time is not regular.

This study can be extended to other machining processes by using more cutting parameters, tool geometries and different cutting tool and work piece materials. The Study can be extended by comparing the experimental and predicted values by using some **Optimization methods.**

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