

**International Journal of Innovative Research in Science,
Engineering and Technology***(An ISO 3297: 2007 Certified Organization)***Vol. 4, Special Issue 6, May 2015**

Optimization of EDM Parameters for Welded Dissimilar Grades of Stainless Steel

G.Pradeep kumar¹, P.Rajkumar¹, S.Muralidharan¹**Vijaykumar P², Sabariganesh R², Sakthivel C²**¹ Assistant Professor, Department of Mechanical Engineering, Muthayammal Engineering College, Tamil Nadu, India.² Students, Department of Mechanical Engineering, Muthayammal Engineering College, Rasipuram, Tamil Nadu, India

ABSTRACT: This paper aims to investigate the optimal set of process parameters such as current, pulse ON time and Voltage in Electrical Discharge Machining (EDM) for welded dissimilar grades of stainless steel. This experiment is to identify the variations in three characteristics such as material removal rate and Tool wear rate on the work for machining using copper electrode. Here, two different grades of stainless steel namely Grade 202 and Grade 304 which are joined by arc welding. Stainless steel electrode is used for welding. Then, a square shaped cut is made in such a manner that the cut passes over the weldment using ZNC EDM for each combination of parameters considered according to the L₂₇ Orthogonal Array. Thus, the machining parameters for EDM were optimized for achieving the combined objectives of higher rate of material removal and lower wear rate on tool on the work material considered in this work.

I. INTRODUCTION

Most of the published papers on EDM are about the applications with EDM to meet the needs for industrial applications. Many of them generally mention about technology, significant machining parameters such as voltage, current, etc., affecting the machining qualities, its machining ability on different type materials, material removal rate of workpiece and wear ratios of tool electrode and so on. Advantages and disadvantages of EDM as a machining technique are also generally reported in several papers. In recent years, EDM researchers have explored a number of ways to improve the sparking efficiency including some unique experimental concepts that depart from the EDM traditional sparking phenomenon. Despite a range of different approaches, this new research shares the same objectives of achieving more efficient metal removal coupled with a reduction in tool wear and improved surface quality. The Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR) is measured and recorded for detailed analysis. This paper aims to fill the gap in the existing literature with respect to the processing of dissimilar grades of stainless steel with EDM.

II. EXPERIMENTAL SETUP AND METHODOLOGY

In EDM, a potential difference is applied between the tool and work piece. Both the tool and the work material are to be conductors of electricity. The tool and the work material are immersed in a dielectric medium. Generally kerosene or deionized used as the dielectric medium.

A gap is maintained between the tool and the work piece. Depending upon the applied potential difference and the gap between the tool and work piece, an electric field would be established. Generally the tool is connected to the negative (Cathode) terminal of the generator and the work piece is connected to positive (Anode) terminal. As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces.

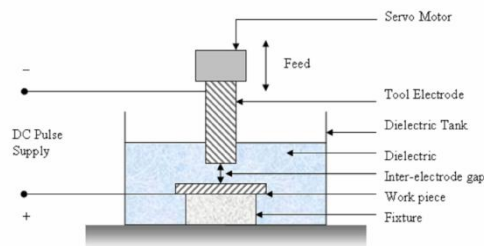
If the work function or the bonding energy of the electrons is less, electrons dielectric medium. As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules. Such collision may result in ionization of the dielectric molecule depending upon the work function or ionization dielectric molecule and the energy of the electron. Thus, as the electrons get accelerated, more positive ions and electrons would get generated due to collisions. This cyclic process would increase concentration of electrons and

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ions in the dielectric medium between the tool and the job at the spark gap. The concentration would be so high that the matter existing in that channel could be as “plasma”. The electrical resistance of such plasma channel would be very less. Thus all of a sudden, a large number of electrons will flow from the tool to the job and ions from the job to the tool. This is called avalanche motion of electrons. Such movement of electrons and ions can be visually as a spark.



Thus the electrical energy is dissipated as the thermal energy of the spark. The high speed electrons then impinge on the job and ions on the tool. The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux.

Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000°C. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially.

As the potential difference is withdrawn, the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark. Thus to summarize, the material removal in EDM mainly occurs due to formation of shock waves as the plasma channel collapse owing to discontinuation of applied potential difference. Generally the work piece is made positive and the tool negative. Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal. Similarly, the positive ions impinge on the tool leading to tool wear. In EDM, the generator is used to apply voltage pulses between the tool and the job. A constant voltage is not applied.

2.1 Why dissimilar grades?

The material selection plays the vital role here. The material to be select should achieve the objective of our project. Firstly, the material should possess properties for welding. It should resist high temperature, and possess high strength and toughness. Secondly, that material should possess properties for EDM. It is primarily used for hard metals or those that would be impossible to machine with traditional techniques. Materials must be electrically conductive. So it does not work on materials such as glass or ceramic, or most plastics. It should be capable of machining geometrically complex or hard material components. Then the availability of the material should be high.

When stainless steel parts such as nuts and bolts are forced together, the oxide layer can be scraped off, allowing the parts to weld together. When forcibly disassembled, the welded material may be torn and pitted, an effect known as galling. This destructive galling can be avoided by the use of dissimilar materials for the parts forced together, for example bronze and stainless steel, or even different types of stainless steels (martensitic against austenitic). However, two different alloys electrically connected in a humid environment may act as Voltaic pile and corrode faster. Nitronic alloys made by selective alloying with manganese and nitrogen may have a reduced tendency to gall. Additionally, threaded joints may be lubricated to prevent galling.

Over the years since the start of the development of stainless steels the number of grades has increased rapidly. There are over 150 grades of stainless steel, of which fifteen are most commonly used. Out these, we are selecting Grade 202 and Grade 304. The reasons for selecting these grades are following.

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Element	Mn	Si	Cr	Ni	P	S	N
Weight %	7.5-10.0	1.00	17.0-19.0	4.0-6.0	0.06	0.03	0.25

Table 1 STAINLESS STEEL GRADE 202

Element	C	Cr	Fe	Mn	Ni	P	S	Si
Weight %	Max 0.08	18 - 20	66.345 - 74	Max 2	8 - 10.5	Max 0.045	Max 0.03	Max 1

Table 2 STAINLESS STEEL GRADE 304

2.2 Workpiece Preparation

The two grades of stainless steel such that Grade 202 and Grade 304 bought with 4 feet length, 6mm thickness and 50mm width each, weighed 3.546kg and 3.470kg. Initially, The material cut with 50mm in length each by Grinding Cutter. Now, the workpiece shaped as 50mm length, 6mm thickness and 50mm width.

2.3 Geometry & Welding joint

The workpiece was need to prepare for welding. Welds can be geometrically prepared in many different ways. The five basic types of weld joints are the butt joint, lap joint, corner joint, edge joint, and T-joint. Many welding processes require the use of a particular joint design; Some processes can also be used to make multipass welds, in which one weld is allowed to cool, and then another weld is performed on top of it. This allows for the welding of thick sections arranged in a single-V preparation joint. We chosen butt joint for experiment. Here, V groove in work was achieved by grinding. The cross section view is shown in below figure.



Figure 1 Welding Joint

2.4 IMPORTANT PARAMETERS OF EDM

1. Voltage
2. Current
3. Pulse on time
4. Pulse off time

2.5 Electrode Material

Tool material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localized temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM.

2.5.1 Copper

Copper is generally used as an electrode material. It can be extruded or drawn and then machined to required size and shape It has low wear under both Roughing and Finishing operations and has the capacity to remove large amounts of material.

2.5.2 Electrode Preparation

Here, 25mm² copper electrode is used for experimentation. The copper electrode bought with lenth of one feet. It is cut with 25mm legh by Wire Cut EDM. Usually, Wire Cut EDM is used for achieving high surface finish. We are in need of high surface finish for effective sparking efficiency. Then the electode made as 25mm square. Finally, the thread is made on one surface for fitting in tool rod. Thus, Electrode preparation achieved.

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2.5 Experimental details

Design of experiment is an effective tool to design and conduct the experiments with minimum resources. Orthogonal Array is a statistical method of defining parameters that converts test areas into factors and levels. Test design using orthogonal array creates an efficient and concise test suite with fewer test cases without compromising test coverage. In this work, L27 Orthogonal Array design matrix is used to set the control parameters to evaluate the process performance.

A depth of 1.5mm was produced by EDM process with the help of copper electrode on stainless steel as work piece material for each combination of parameters considered according to the Orthogonal Array. The work piece and tool electrode were weighed before and after the machining by using the electronic weigh-balance to calculate the material removal rate and the tool wear rate. The surface roughness of the surface machined was evaluated using a surface roughness-testing machine.

2.6 Calculation

2.6.1 Material Removal Rate (MRR)

The material MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time and density of the material.

$$MRR = \frac{W_{jb} - W_{ja}}{T}$$

Where,

W_{jb} = Weight of workpiece before machining.

W_{ja} = Weight of workpiece after machining.

t = Machining time

2.6.2 Tool Wear Rate (TWR)

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time. That can be explain this equation

$$TWR = \frac{W_{tb} - W_{ta}}{t}$$

Where,

W_{tb} = Weight of the tool before machining.

W_{ta} = Weight of the tool after machining.

t = Machining time

S.NO	VOLTAGE (V)	CURRENT (Amps)	PULSE- ON TIME (μs)	MACHINING TIME (Sec)	MRR (cm ³ /sec)	TWR (gm/sec)
1	1	3	500	12413	0.00012	0.000104
2	1	3	700	11726	0.000056	0.0000064
3	1	3	900	9165	0.000074	0.0000146
4	1	15	500	3226	0.000972	0.0000126
5	1	15	700	2702	0.000314	0.000406
6	1	15	900	1893	0.002607	0.00048
7	1	27	500	520	0.001727	0.000185
8	1	27	700	514	0.001859	0.000206
9	1	27	900	337	0.00198	0.001222
10	3	3	500	8122	0.00007	0.000085
11	3	3	700	6858	0.000078	0.0000066
12	3	3	900	8723	0.000074	0.0000087
13	3	15	500	979	0.000901	0.000061
14	3	15	700	1164	0.000928	0.000054
15	3	15	900	862	0.000806	0.000011
16	3	27	500	474	0.001699	0.000462
17	3	27	700	482	0.00191	0.000128

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18	3	27	900	562	0.001926	0.000311
19	5	3	500	5592	0.000105	0.000013
20	5	3	700	534	0.000214	0.000713
21	5	3	900	7100	0.000098	0.0000048
22	5	15	500	1073	0.000815	0.0000118
23	5	15	700	1007	0.000865	0.0000117
24	5	15	900	392	0.000978	0.000471
25	5	27	500	570	0.001558	0.000328
26	5	27	700	403	0.001472	0.000102
27	5	27	900	428	0.001916	0.000039

Table 3 Results for MRR and TWR

III. RESULTS AND DISCUSSION

3.1 S/N Ratio Graph for MRR

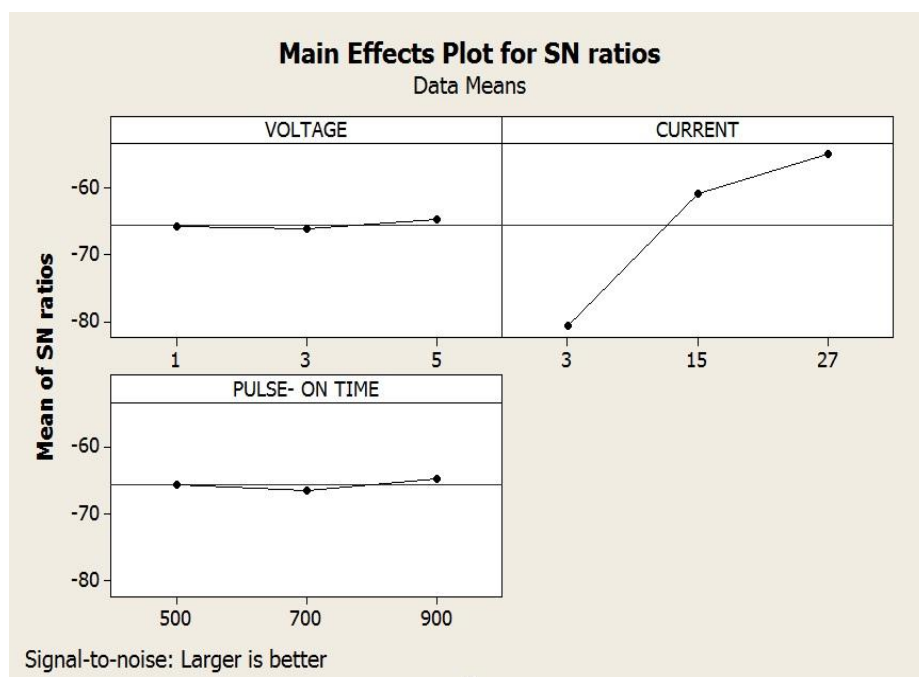


Figure 2 S/N Ratio Graph for MRR

In this Graphs, Best Machining Condition for MRR were Voltage=5V, Current = 27 Amps and Pulse on Time=900 μ s

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3.2 S/N Ratio Graph for TWR

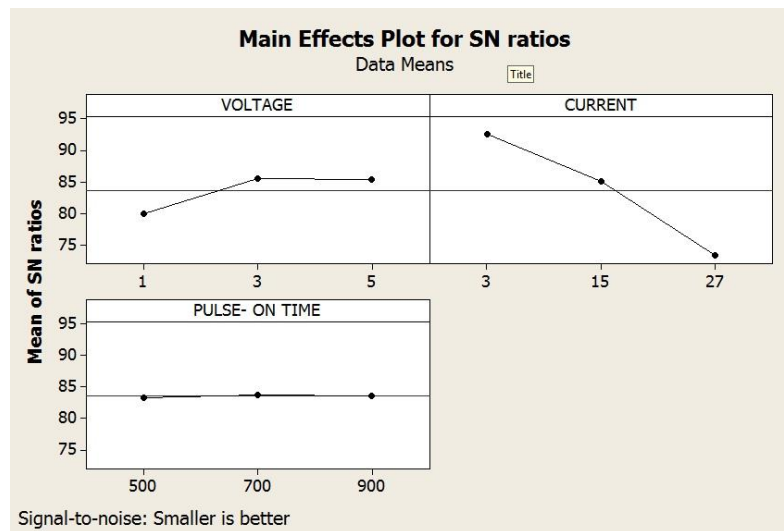


Figure 3 S/N Ratio Graph for TWR

In this Graphs, Best Machining Condition for TWR were Voltage=1V, Current = 27 Amps and Pulse on Time=500 μ s

IV. CONCLUSION

Results from an experimental investigation on the effect of machining parameters on EDM process characteristics have been presented. The conclusions are as follows:

1. The Material Removal rate is directly proportional to Pulse On time and Current,
2. The tool wear ratio is directly proportional to Pulse on Time and Current and is inversely proportional to Voltage,

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