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EXPERIMENTAL ANALYSIS OF ELECTRICAL DISCHARGE MACHINING PROCESS PARAMETERS USING TAGUCHI METHOD

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ABSTRACT : Electrical Discharge Machining is a thermo-electric non-traditional machining process in which material removal takes place through the process of controlled spark generation between a pair of electrodes which are submerged in a dielectric medium. It is recognized as an efficient method of producing dies and machining of hard material such as ceramics and high strength metal matrix composites for the modern metal industry. In this investigation, response Taguchi method is used to investigate the effect of four controllable input variables namely: discharge current, pulse off time, pulse on time and gap voltage on material removal rate. In the present work, the experiments were conducted using response surface methodology, to ascertain the effect of EDM process parameters on material removal rate (MRR) of cast iron by using tool material Brass. The significant coefficients are obtained by performing analysis of variance (ANOVA). It is found that discharge current and pulse duration are significant factors. Taguchi method is a precision methodology that needs only 27 experiment to assess the condition.

Keywords: Electrical Discharge Machining, Material Removal Rate, ANOVA, Taguchi method.

1)INTRODUCTION: The Electrical Discharge Machining was first traced far back in 1770's by English scientist Joseph Priesty who discovered the erosive effect of electrical discharges or sparks (1). In the year 1943 it was developed by Lazarenko. Nowadays it is an acceptable technology all over the world. Traditional machining processes that make chips formation have a number of inherent limitations which limit their application in industry. Large amount is expanded to produce unwanted chip which must be removed and discarded. Much of the machining energy ends up with an undesirable heat that often produces problem of distortion and surface making. Cutting force required that the workpiece be held which can also lead to distortion. Unwanted distortion, residual stress and burrs caused by machining process often require further processing. Finally, some geometries which are difficult to machining by conventional methods. In this sense that the metal like tungsten, hardened stainless steel, titanium, some high strength steel alloy etc. are such that they can't be machined by conventional method but required some special technique. EDM is that most important machining technique.

The Main advantage of this process is that the machining process is not depend on the hardness, toughness, and brittleness of the work material and can produce any intricate shape on any workpiece material by a suitable control over various physical parameters of the process. In this machining process there is no direct contact between tool and workpiece. The metal is removed from the workpiece through localized melting and vaporization of material. Electric sparks are generated between two electrodes when electrodes are held at a small distance from each other in a dielectric medium and high potential difference is applied across them. Localized regions of high temperatures are formed due to the sparks occurring between the two electrode surfaces. Workpiece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter electrode gap by the dielectric flow in the form of debris particles

1.1 ELECTRIC DISCHARGE MACHINING

Electric Discharge Machining (EDM) is a modern manufacturing process machining process, where electrically conductive material is removed by controlled erosion through a series of electric sparks of short duration and high current density between the electrode and the workpiece were both are submerged in a dielectric bath, containing kerosene or distilled water [4]. During this process thousands of sparks per second are generated, and each spark produces a tiny crater in the material along the cutting path by melting and vaporization. Generally the material is removed by erosion process.

The top surface of the workpiece subsequently re-solidifies and cools at a very high rate. The application of this process is mostly found in press tools and dies, plastic moulding, forging dies, die castings, aerospace, automotive, surgical components manufacturing industries etc. This process is not restricted by the physical and metallurgical properties of the work material as there is no physical contact due to high energy electro thermal erosion between the tool and the workpiece. It uses electro thermal phenomenon, coupled with surface irregularities of the electrodes, interactions between two successive discharges and presence of debris particles makes the EDM process too abstruse, so that complete and accurate physical modeling of the process has been observed to be difficult to establish. The favorable EDM process parameters selection is required for obtaining the best machining performance by increasing the production rate at the same time reducing the machining time. The process parameters are generally determined based on experience or on handbook values. However, this does not confirm that the chosen machining parameters result in optimal or near optimal machining performance of the EDM process.

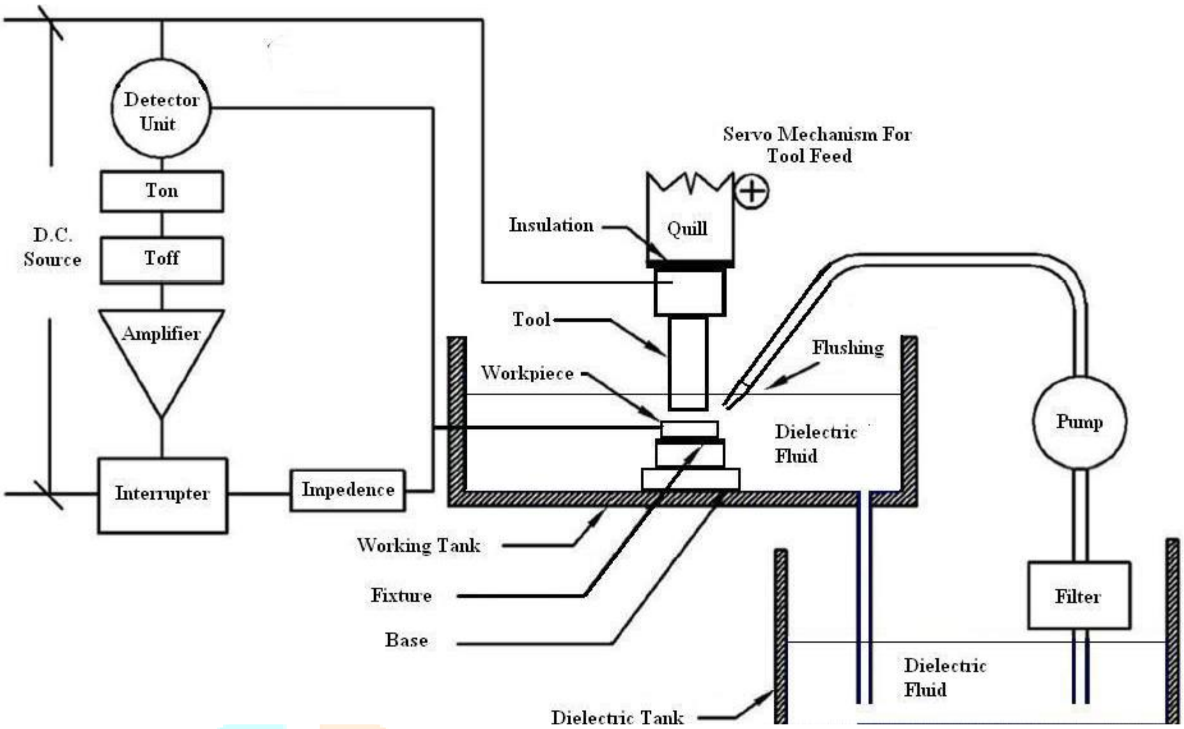


Figure 1.1: Layout of Electrical Discharge Machining

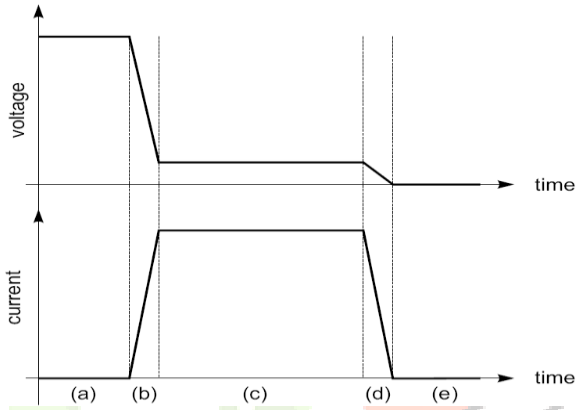


Figure 1.2: Variation of current and voltage in different phases of a spark [4]

layer of metal will recast on the surface of workpiece due to the cooling and collapsing of plasma. The thickness of the layer is around 20 to 100 microns and is known as white layer. Simultaneously, the molten metal pool is absorbed into the dielectric, leaving behind a small crater on the workpiece surface (around 1-500 micrometer in diameter, depending on the current).

1.2 TAGUCHI METHOD

Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Taguchi design method is to identify the parameter settings which render the quality of the product or process robust to unavoidable variations in external noise. The relative "quality" of a particular parameter design is evaluated using a generic signal-to-noise (S/N) ratio. Depending on the particular design problem, different S/N ratios are applicable, including "lower is better" (LB), "nominal is best" (NB), or "higher is better" (HB). As the objective is to obtain the high material removal rate, low tool wear rate, and best surface finish, it is concerned with obtaining larger value for MRR, smaller value of tool wear rate and smaller value of surface roughness. Hence, the required quality characteristic for high MRR is larger the better, which states that the output must be as large as possible, and for tool wear rate and surface roughness is smaller the better, which states that the output must be as low as possible.

1.3 MACHINING PARAMETERS

For the experimental analysis of machining process or to perform efficient machining one should identify the process and performance measuring parameters. The EDM process parameters can be categorized into:

(i) Input or process parameters: The input parameters of EDM process which affects the performance of machining process are discharge current, spark-on time, voltage, duty factor, flushing pressure, workpiece material, tool material, quill-up time, inter-electrode gap, working time, and polarity. So, process parameters are selected accordingly for optimal machining condition.

2.EXPERIMENT WORK

2.1 EXPERIMENT SETUP

For this experiment the whole work is done by using Electrical Discharge Machine having provision of programming in the Z-vertical axis and manually operated X and Y axes. The tool is made of cathode and the workpiece as anode. Commercial grade EDM oil (specific gravity=0.763 kg/m^3, freezing point= 94^{o}c) was used as dielectric fluid with lateral flushing (pressure of 0.3kgf/cm^2) system for effective flushing of machining from working gap region.

Fig 2.1 EDM MACHINE

2.2 SPECIFICATIONS OF OUR SPARKONIX EDM MACHINE

Table.2.1 Specification of EDM Machine

MACHINING UNIT	S 50 (ZNC)
TANK SIZE (mm)	900×550×375
TABLE SIZE (mm)	600×400
LONG-CROSS TRAVEL (mm)	350×2×25
VERTICAL FILTER	14”, 1O MICRON
QUILL (mm)	250
MAXIMUM HEIGHT OF WORKPIECE (mm)	350
MAXIMUM WEIGHT OF WORKPIECE (kg)	550
MAXIMUM ELETRODE WEIGHT (kg)	35
PARALLELISM OF TABLE SURFACE WITH TRAVEL	0.02
SQUARENESS OF THE ELECTRODE TRAVEL	Z

2.3 MATERIAL OF WORKPIECE: There are a lot of difficulty occur when to provide advance material such as super alloys, ceramics, and metal matrix composites to use in this research. Hence, the reliable materials used for this project are INCONEL 625

2.3.1 INCONEL 625

Inconel 625 is a nickel-based superalloy that possesses high strength properties and resistance to elevated temperatures. It also demonstrates remarkable protection against corrosion and oxidation. Its ability to withstand high stress and a wide range of temperatures, both in and out of water, as well as being able to resist corrosion while being exposed to highly acidic environments makes it a fitting choice for nuclear and marine applications.

Table 2.2: Composition of workpiece

Material Property	**Inconel 625**
Tensile strength (MPa)	690
Yield strength (MPa)	275
Thermal expansion coefficient	1.28 x 10^{-5} 1/K (at 20°C)
Melting Point (°C)	1300
Material corrodes	0.188 mm per year

2.4 SELECTION OF TOOL ELECTRODE

The present experiments have been performed using Brass electrodes (99.7% Cu, 0.12% Zn, 0.02% Pb, 0.02% Sn) with positive polarity. The electrode used is 3mm in diameter and 50 mm in height. Commercial kerosene was used as a dielectric fluid. The machining was generally carried out for a fixed time interval and the amount of metal removed was measured by taking the difference in weights of the workpiece before and after electrical discharge machining.The surface roughness (Ra) of each machined workpiece was measured using the Mitutoyo Talysurf (SJ – 201). Each experiment was repeated three times for better results and the average was calculated. For measuring the gap size, the diameter of the resulted hole in the workpiece block was measured three times at different locations and the average was calculated. Profile projector 10 multiplied by magnification was used to measure these diameters. The gap size (GS) was then calculated by the difference between the radius of the average measured diameter and the radius of the electrode.

2.4.1 Brass Electrode

The choice of the electrode depends upon the performance criteria required (MRR, surface roughness machining stability) and also upon the electrode manufacturing constraints. A good electrical conductor will be selected first in order to create the discharges. This material must have high melting point and vaporizing temperature as well as high thermal diffusivity to ensure the geometrical stability of the electrode. This is the first choice as EDM tool electrode. It can be produced by casting or machining. Brass electrodes with very complex features are formed by chemical etching or electroforming. Brass was the best tool material used for EDM machine. Brass is often used in situations in which it is important that sparks not be struck, such as in fittings and tools used near flammable or explosive materials. Brass is similar to bronze, another alloy containing Brass, with tin in place of zinc. both bronze and brass may include small proportions of a range of other elements including arsenic, lead, phosphorus, aluminum, manganese, and silicon. The distinction between the two alloys is largely historical, and modern practice in museums and archaeology increasingly avoids both terms for historical objects in favour of the more general "Brass alloy".

Table 2.3 the Physical Properties of Brass Electrode

Physical properties	**Value**
Electrical resistivity at 20 (μΩ/m)	~0.6 - 0.9 x 10^{-7}
Electrical conductivity (%)	28
Thermal conductivity (W/mK)	109
Melting point (° C)	900-940
Specific heat (cal/g ° C)	0.380
Poisson ratio	0.331
Density (kg / m^{3})	8700

3.READINGS AND CALCULATIONS

3.1 SELECTIONS OF PROCESS PARAMETER

VARIABLE	CODING	LEVEL		
		1	2	3
Peak current (Amps)	A	3	6	9
Pulse on Time	B	300	600	900
Pulse off Time	C	30	60	90

3.2 Experimental results for material removal for material Inconel 625:

Run	Ip	Ton (µs)	Toff (µs)	Wjb (gm)	Wja (gm)	Machining Time(sec)	MRR (m^3/sec)	TWR
1	3	3	3	17.93	17.89	149	0.0001286	0.0106
2	3	3	6	17.89	17.83	236	0.0000813	0.005247
3	3	3	9	17.83	17.73	253	0.0000686	0.02367
4	3	6	3	17.73	17.62	87	0.0002068	0.07585
5	3	6	6	17.62	17.56	109	0.0001750	0.03282
6	3	6	9	17.56	17.48	139	0.0001335	0.03447
7	3	9	3	17.48	17.42	70	0.0002545	0.0509
8	3	9	6	17.42	17.36	87	0.00021946	0.04114
9	3	9	9	17.36	17.29	105	0.0001708	0.03986
10	6	3	3	17.29	17.13	59	0.0003457	0.1627
11	6	3	6	17.13	16.98	99	0.0001986	0.0903
12	6	3	9	16.98	16.87	129	0.0001481	0.0509
13	6	6	3	16.87	16.91	36	0.0005617	0.09912
14	6	6	6	16.81	16.75	48	0.0004229	0.0746
15	6	6	9	16.15	16.57	60	0.0003278	0.1788
16	6	9	3	16.57	16.51	30	0.0000631	0.1183
17	6	9	6	16.51	16.37	35	0.0004256	0.2334
18	6	9	9	16.37	16.26	45	0.0004123	0.7463
19	9	3	3	16.26	16.19	41	0.0004455	0.1006
20	9	3	6	16.19	15.99	70	0.0002648	0.1708
21	9	3	9	15.99	15.93	100	0.0001794	0.0358
22	9	6	3	15.93	15.82	26	0.0006868	0.2518
23	9	6	6	15.82	15.76	41	0.0004572	0.08753
24	9	6	9	15.76	15.60	48	0.0003839	0.1951
25	9	9	3	15.60	15.54	22	0.0006765	0.1623
26	9	9	6	15.54	15.42	27	0.0006941	0.2603
27	9	9	9	15.42	15.26	31	0.0006373	0.3089

Planing matrix of the experiments with the optimal model data

4. MRR Taguchi Table for signal to Noise Ratio

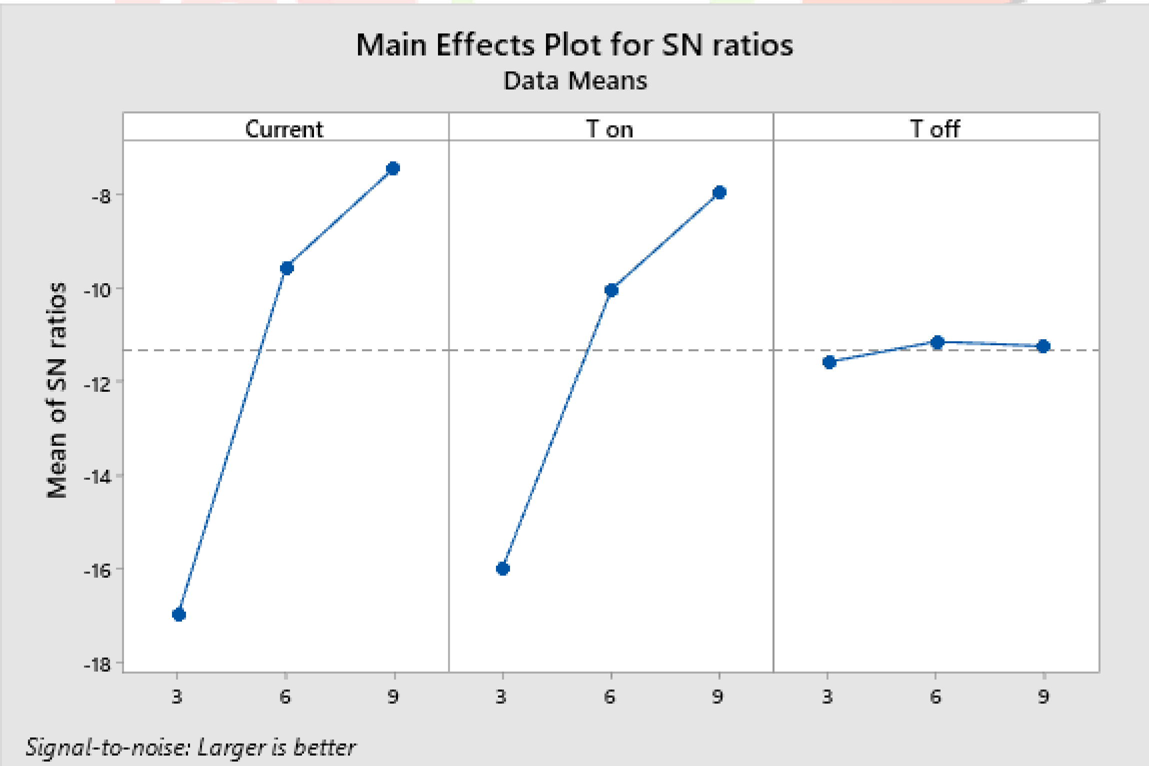
Response Table for Signal to Noise Ratios

Larger is better

Level	Current	T on	T off
1	-16.981	-15.993	-11.587
2	-9.561	-10.039	-11.151
3	-7.449	-7.959	-11.253
Delta	9.531	8.033	0.436
Rank	1	2	3

Response Table for Means

Level	Current	T on	T off
1	0.1598	0.2067	0.3639
2	0.3860	0.3728	0.3573
3	0.4917	0.4579	0.3163
Delta	0.3319	0.2512	0.0476
Rank	1	2	3



4.1 TWR Taguchi Table for signal to noise Ratio

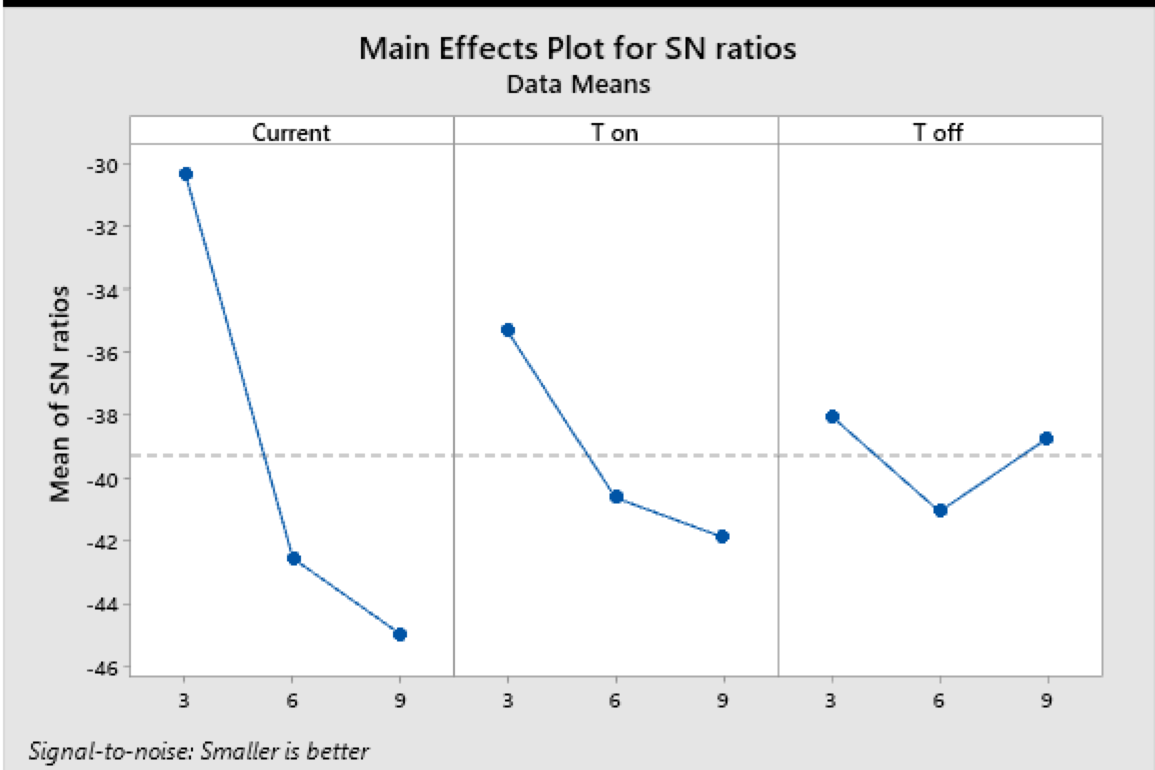
Response Table for Signal to Noise Ratios

Smaller is better

Level	Current	T on	T off
1	-30.29	-35.31	-38.03
2	-42.56	-40.63	-41.07
3	-44.99	-41.90	-38.74
Delta	14.70	6.58	3.04
Rank	1	2	3

Response Table for Means

Level	Current	T on	T off
1	34.95	72.31	119.26
2	128.28	114.61	130.97
3	174.98	151.29	87.98
Delta	140.02	78.97	42.99
Rank	1	2	3



5.CONCLUSION

In this whole thesis the effect of input parameter such as peak current, pulse on time, pulse off time and flushing pressure on output parameter as material removal rate (MRR) and tool wear rate (TWR) have been studied which is based on EDM machining process. The Experiments were conducted under various parameters by considering Taguchi L9 orthogonal array and taking Inconel 625 as work piece and Brass electrode as tool material. From the result it is considered that:For MRR, the most significant factor is found to be pulse on time followed by pulse off time.With change in input parameter the material removal rate changes accordingly.At peak current 9(A), pulse on time 9(µs), pulseoff time 6(µs) and flushing pressure 0.3(kg/cm2) it is observed that the material removal rate becomes high. At peak current 3(A), pulse on time 3(µs), pulse off time 6(µs) and flushing pressure 0.3(kg/cm2) the tool wear rate reduces significantly.

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