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Influence of EDM Process Parameters on Material Removal Rate

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Abstract

Electrical Discharge Machining is a one of an electrical energy based Unconventional Machining Technique. The electrical energy is directly used to remove or cut the metals. It's also called as Spark Erosion Machining or Electro Erosion Machining. The metal is removed by electrical spark discharge between tool (Cathode) and workpiece (Anode). Electrical Discharge Machining is used in Mould and Die making industries, Automobile industries and also making of Aerospace components.

Key Words: EDM, MRR, TWR, SR, Process, Parameters.

Introduction

Electrical Discharge Machining is a one type of an Unconventional Machining Technique. It is an electrical energy based unconventional machining process. The electrical energy is directly used to remove or cut the metals. It's also called as Spark Erosion Machining or Electro Erosion Machining. The metal is removed by electrical spark discharge between tool (Cathode) and workpiece(Anode). Electrical Discharge Machining is used in mould and die making industries, Automobile industries and also making of Aerospace components.

Working Principle of EDM

EDM consists of the following components,

1. Power Supply Unit
2. Dielectric Fluid Reservoir, Pumps, Filters and Control Valve.
3. Workpiece holder and Table
4. Tool holder
5. Servo Control Mechanism

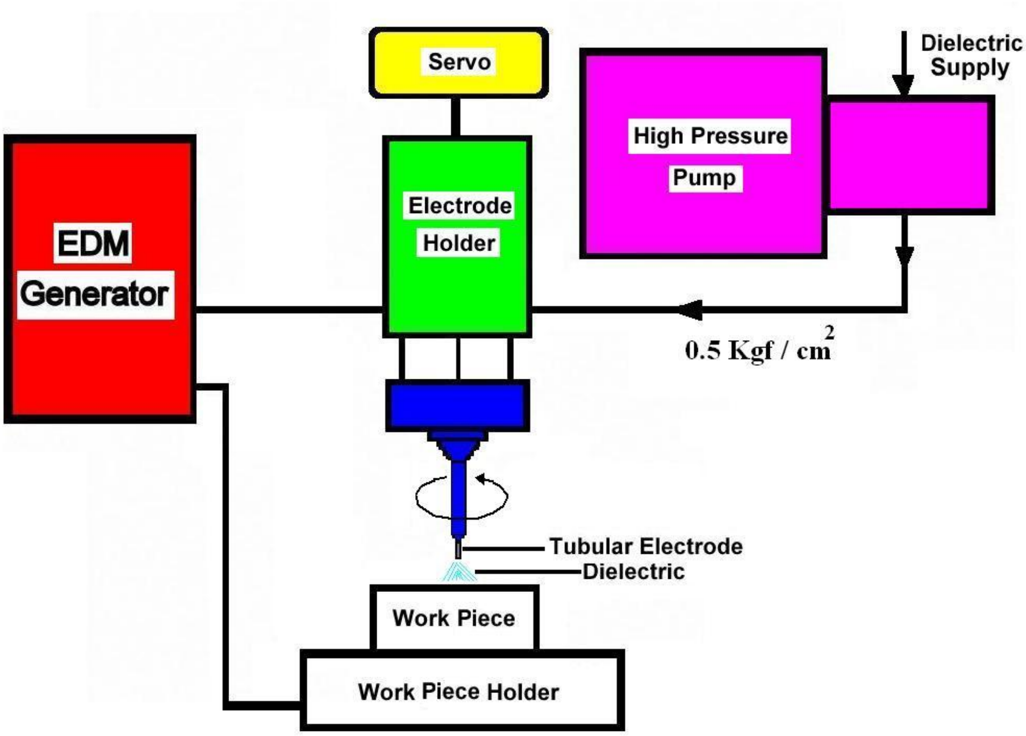

Figure 1: Diagram of EDM

The tool and workpiece are directly connected with DC power supply. The workpiece is connected into positive terminal and tool is connected into negative terminal of DC supply. The tool and workpiece are submerged in the dielectric medium. The servo feed mechanism is used to give a constant gap (spark gap) between the tool and workpiece. Figure 1 shows the schematic diagram of EDM.

When the DC supply is given to the circuit, the voltage across at 250V and high spark is produced at the spark gap. So that the dielectric breaks down and electrons are emitted from cathode, the gap is ionized and thousands of sparks/sec occurred at the gap. This high spark produces high temperature. Due to that high temperature and high pressure the metal is removed and flushed away by the dielectric fluid. When the voltage drops, the dielectric fluid got deionised [1].

Literature Survey

Kuppan et al. worked on the Inconel 718 by making deep hole drilling with EDM. Peak current, pulse-on-time, duty factor and electrode speed were chosen as the parameters were considered. The output responses were metal removal rate, depth of average surface roughness. The experimented were planned using central composite design. The results revealed that metal removal rate is more influenced by peak current, duty factor and electrode rotation, and MRR is increased with increase in current and duty factor and electrode speed, where as depth of average surface roughness is increased with increase in peak current, electrode speed and pulse on time [2].

Bozdana et al. presented a comparative experimental study on machining and surface characteristics of through and blind holes (Ø1 mm) produced on aerospace alloys of Ti-6Al-4V and Inconel 718 by fast hole rotary EDM process using tubular hollow copper and brass electrodes. It was revealed that the achievement of desirable MRR and EW values and acceptable topography of machined surfaces were dependent upon the appropriate selection of tool electrode material and the choice of making through/blind hole. The brass electrode has provided a superior MRR for the production of through and blind holes on IN 718 and Ti 64 test pieces as compared with copper electrode [3].

O. Yilmaz et al. performed an intelligent and automated approach for EDM hole drilling of super alloys on Ti-6Al-4V and Inconel 718 alloys. The mathematical model was created to optimize the parameters using ANOVA. Pulse current, pulse duration, capacitance, are performed on material removal rate, tool wear rate and surface roughness to minimize the time and cost while drilling operations [4].

Yilmaz et al. presented a comparative experimental investigation of EDM fast hole drilling of Inconel 718 and Ti-6Al-4V by using single and multi-channel tubular electrodes made of brass and copper materials. The experimental results revealed that the single-channel electrode has comparatively better material removal rates and lower electrode wear ratio and multi-channel electrodes produce better surfaces than single channel electrodes [5].

S.Sudhakara et al. performed an experimental investigation of machining of Inconel-718 using EDM process. An electrolytic rectangular copper block of 12x 8 mm was selected as a tool electrode. The output response was measured were Material remove rate, Avg. Surface Roughness, Hardness. The results are revealed that how material removal rate, surface roughness and hardness are influenced by peak current, duty factor and pulse-on time [6].

S. Dhanabalan et al. carried out optimization of machining parameters of EDM while machining Inconel 718 for form tolerance and orientation tolerance. A Grey relational coefficient is used to analyze the relational degree of multiple responses like MRR, TWR, form tolerance and orientation tolerance through the process parameters of Peak current, Pulse on, Pulse off for machining of Inconel 718 by using hexagonal and square profile copper electrodes [7].

Experimental Setup

The experiments were conducted by using die sinking SPARKNOIX – Electrical Discharge Machine with servo head (constant gap). The Kerosene is used as a dielectric medium at a constant pressure of 0.5kgf/cm^3.

Figure 2: Experimental Setup

The experiments are done with positive polarity of electrode. The figure 2 shows the experimental setup of the Electric Discharge Machining. The weight of the work piece and electrode were measured by using SHIMADZU BL series electronic balance with an accuracy of 0.001g for accuracy of every trial run.

Experimental Details

A. Selection of Workpiece Material

For this experiment, Inconel 718 has been selected as a workpiece material due to the following reasons,

1. It is used for their high yield, tensile and creep rupture properties.
2. Used for making Jet engines, aerospace components, Gas turbine parts, rocket engines and nuclear power plant components like reactor and pumps.
3. Less research work has been done on this material.

***B.** Selection of Tool Material*

For this experiment the Copper has been selected as tool material. The reason for selecting the copper as electrode,

1. High electrical conductivity
2. High melting point
3. Easily available

C. Selection of Process Parameters
There are many process parameters are taken into the account for improving the performances of Electrical Discharge Machining. These process parameters are Peak Current, Pulse on time, Pulse off time, Voltage, Flushing Pressure, Tool shape, Cutting Speed, Duty factor, Electrode rotations, etc.

Here the Peak Current, Pulse on time and Pulse off time are taken as the process parameters for this experimental work. The literature surveys are concluded that these all are the most influencing factors which affect the output measures directly.

D. Selection of Process Parameters Ranges

1. Peak Current (I_P)
Peak Current is the most influencing factor in EDM. It is nothing but the amount of power used in EDM. Metal Removal Rate is directly proportional to the Peak Current. The experiments were conducted at 4A, 8A and 12A.

2. Pulse on Time (T_{on})
It is the duration of time (μs) for which the current is allowed to flow per one complete cycle. Amount of energy applied during this on-time is directly proportional to material removal rate. The experiments were conducted at 200 μs, 400 μs and 600 μs. .

3. Pulse off Time (T_{off})
It is the time duration between the sparks. And this Pulse off time allows the molten material to solidify and to be wash out of the gap. The experiments were conducted at 20 μs, 40 μs and 60 μs.

E. Selection of Output Measures
Many Output responses are measured by varying the input parameters. These responses are Material Removal Rate (MRR), Tool Wear Rate (TWR), Surface Roughness (SR), Over Cut (OC) and Surface Quality (SQ) etc. Here MRR is taken as the output measures for this experimental work.

1. Material Removal Rate (MRR)
MRR is the ratio of the difference of weight of the workpiece material before and after machining to the machining time. The MRR is calculated by,

$$\text{MRR (g/min.)} = \frac{\text{Initial weight of w/p - Final weight of w/p}}{\text{Time of Machining}}$$

Results and Discussion
The experiments were conducted by using die sinking SPARKNOIX - Electrical Discharge Machine having maximum 12 A current as maximum rating. The work piece was connected with positive terminal and Copper tool was connected with negative terminal of the DC power supply. Kerosene was used as a dielectric fluid

with a pressure of 0.5 kgf/cm^2 and side flushing technique was used to conduct all the experiments.

The weight of the work piece and electrode were measured by using SHIMADZU BL series electronic balance with an accuracy of 0.001 g for accuracy of every trial run. Design-Expert v7 (by Stat-Ease, Inc.), software was used to design the experiments, analyze the results on EDM process.

The three machining parameters were chosen for controlling factor, and each parameter was designed to have three levels, namely small, medium and large. They are listed in the table 1 is shown below.

Table 1: Level of Process Parameters

Parameter	Unit	Level 1	Level 2	Level 3
Peak Current	A	4	8	12
Pulse on time	µs	200	400	600
Pulse off time	µs	20	40	60

For Experimental design the full factorial method ($L=m^n$) is used to find out number of readings. The 27 experimental runs were conducted in duplicate, the average value of MRR and TWR for Inconel 718 along with the Design of experiments are given in the following table 2.

Table 2: MRR Values Using Design of Experiments

Run No.	Current (A)	T on (µs)	T off (µs)	Avg. MRR (g/min)
1	4	200	20	0.0496
2	4	200	40	0.0332
3	4	200	60	0.0315
4	4	400	20	0.0864
5	4	400	40	0.0713
6	4	400	60	0.0651
7	4	600	20	0.1157
8	4	600	40	0.1054
9	4	600	60	0.1161
10	8	200	20	0.1010
11	8	200	40	0.1048
12	8	200	60	0.0894
13	8	400	20	0.2570
14	8	400	40	0.1995
15	8	400	60	0.1760
16	8	600	20	0.2523

17	8	600	40	0.2067
18	8	600	60	0.1475
19	12	200	20	0.1538
20	12	200	40	0.1284
21	12	200	60	0.1922
22	12	400	20	0.3604
23	12	400	40	0.4188
24	12	400	60	0.2854
25	12	600	20	0.3260
26	12	600	40	0.3230
27	12	600	60	0.3118

Effect on Material Removal Rate

A. Effect of Peak Current

Table 3 shows the relationship between variation of Metal Removal Rate and Current at constant Pulse on Time and Pulse off Time.

Table 3: Variation of MRR with Constant T_{on} &T_{off}

SL. NO.	Current (A)	T_{on} (μs)	T_{off} (μs)	MRR (g/min)
1	4	200	20	0.050
2	8	200	20	0.101
3	12	200	20	0.154
4	4	400	40	0.171
5	8	400	40	0.200
6	12	400	40	0.419
7	4	600	60	0.116
8	8	600	60	0.148
9	12	600	60	0.312

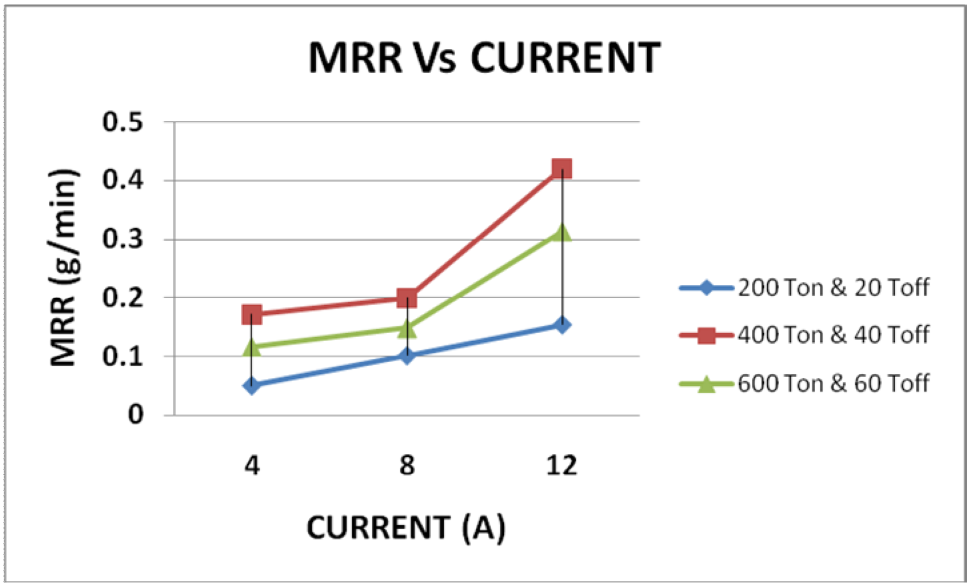

Figure 3: Variation of MRR with Current

Figure 3 shows the relationship between metal removal rate (g/min) and current. From the figure, we can observe that, when the current is increased at constant pulse on time and pulse on time, the metal removal rate is increased. When the current is increased from 4A to 12A the metal removal rate is increased with current. This is because; when current are high, melting starts earlier.

B Effect of Pulse on Time

Table 4 shows the relationship between variation of Metal Removal Rate and T_{on} at constant Current and Pulse off Time.

Table 4: Variation of MRR with Cons. Current & T_{off}

SL. NO.	Current (A)	T_{on} (µs)	T_{off} (µs)	MRR (g/min)
1	4	200	20	0.050
2	4	400	20	0.086
3	4	600	20	0.116
4	8	200	40	0.105
5	8	400	40	0.200
6	8	600	40	0.207
7	12	200	60	0.192
8	12	400	60	0.285
9	12	600	60	0.312

Figure 4 shows the relationship between metal removal rate (g/min) and T_{on}. From the figure, we can observe that, when the Pulse on Time is increased at constant

Current and pulse off time, the metal removal rate is increased. When the Pulse on Time is increased from 200µs to 600 µs the metal removal rate is increased with constant current and Pulse off Time.

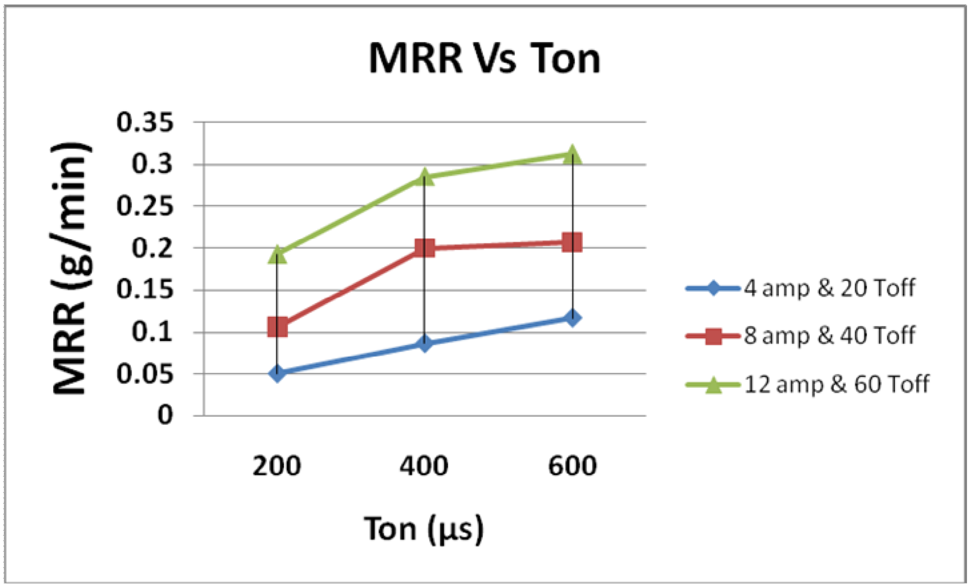

Figure 4: Variation of MRR with T_{on}

C. Effect of Pulse off Time

Table 5 shows the relationship between Metal Removal Rate and T_{off} at constant Current and Pulse on Time.

Table 5: Variation of MRR with Const. Current & T_{on}

SL. NO.	Current (A)	T_{on} (µs)	T_{off} (µs)	MRR (g/min)
1	4	200	20	0.050
2	4	200	40	0.033
3	4	200	60	0.032
4	8	400	20	0.257
5	8	400	40	0.200
6	8	400	60	0.176
7	12	600	20	0.326
8	12	600	40	0.323
9	12	600	60	0.312

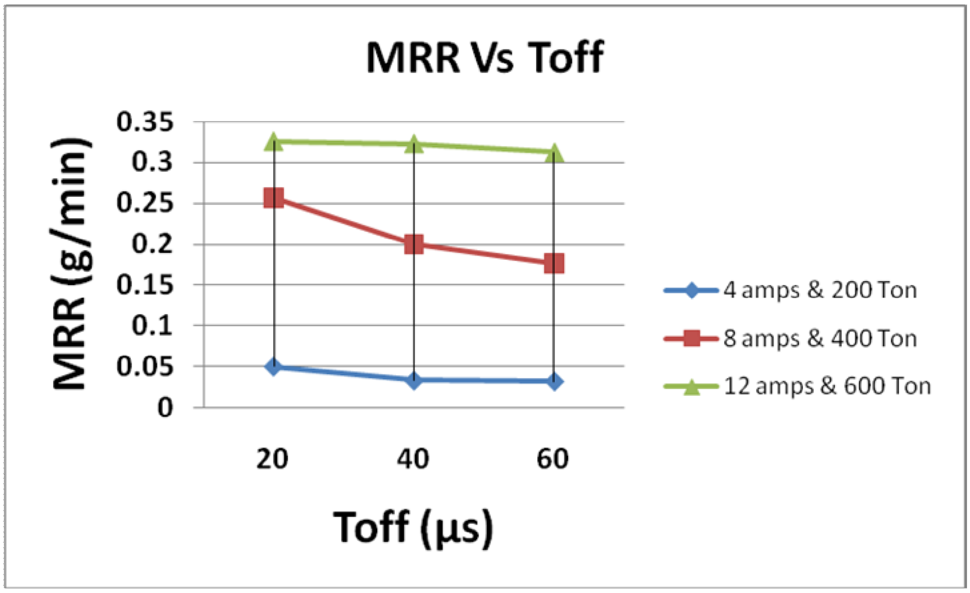

Figure 5: Variation of MRR with T_{off}

Figure 5 shows the relationship between Metal Removal Rate (g/min) and T_{off}. From the figure, we can observe that, when the Pulse off Time is decreased at constant Current and pulse on time, the metal removal rate is increased. When the Pulse off Time is increased from 20µs to 60 µs the metal removal rate is decreased with constant current and Pulse on Time.

Conclusions

In this experimental study, the effect of Peak Current, Pulse on and Pulse off times on the Material Removal Rate of Inconel 718 was investigated. From the results the conclusions are made as follows,

- Material Removal Rate increases with increasing of peak current. Lower Material Removal Rate is obtained at low value of peak Current and higher Material Removal Rate is obtained at high value of peak Current
- The MRR increases with increase in pulse on time at all value of peak current. Higher Material Removal Rate is obtained at high value of Pulse on time and lower Material Removal Rate is obtained at low value of Pulse on time.
- The MRR increases with decrease in pulse off time at all value of peak current. Higher Material Removal Rate is obtained at low value of Pulse off time and lower Material Removal Rate is obtained at high value of Pulse off Time.

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