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Influence of Polarity of Electro Discharge Machine (EDM) on Surface Roughness (SR) and Metal Removal Rate (MRR) of Low Carbon Steel

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K E Y W O R D S

EDM, Polarity, MRR, Surface roughness (Ra).

A B S T R A C T

Electro discharge machining (EDM) is one of a thermal process that is used for remove of metal from the workpiece by spark erosion. The work of this machine depends on multiple variables. One of the more influential variants on this machine is the change of polarity and the use of this variable is not wide and the research depends on the polarity of the machinist. Essentially, the polarity of the tool (electrode) is positive and the workpiece is negative, this polarity can be reversed. This paper focuses on the influence of changing the polarity (positive and negative) on the surface roughness and metal removal rate by using different parameters (current, voltages, polarity and Ton). Experiments show that the positive electrode gives (best surface roughness = 1.56 µm when the current = 5 Am and Ton = 5.5 µs) and (best metal removal rate = 0.0180 g/min when the current = 8 Am and Ton = 25 µs). Negative electrode gives (best surface roughness = 0.46 µm when the current = 5 Am and Ton = 5.5 µs) and (best metal removal rate = 0.00291 g/min when the current = 8 Am and Ton = 25 µs).

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1. Introduction

Electrical Discharge Machining (EDM) is a machine that is used for non-traditional manufacturing processes. It is a process that is used to remove material that action during an electrical discharge with short duration and high current density between the tool and workpiece. There are no physical cutting forces between the tool and the workpiece [1]. This device has been constantly developed to produce more speed accuracy and to suit the development of technological progress. It can be produced in this machine tools and complex forms widely used in modern industries manufacturing processes and this device has been constantly developed to produce more speed accuracy and to suit the development of technological progress [2]. There are various and multiple reasons for the removal of materials during this operation, Kang and, Rajorkar (1977) have reported electromechanical and thermal-mechanical theories. The first theory suggests that there is a high electric field that causes the separation of the material molecules from the work, where this electric field exceeds the forces of cohesion in the material lattice and the removal occurs. The second theory (mechanical thermal) states that a variety of electrical effects of discharge are responsible for the melting of the material from the workpiece [3]. Figure 1 shows the working mechanism of EDM and the electrode tool which moves up and down but there is no touching between the electrode and the workpiece. When generating the necessary energy from the power supply during the passage of voltage in the gap spark, it is generated within the gap in a very short period of time. The process of removing the metal is done by melting the particles of the metal. This causes of the presence of the dielectric fluid concentrates the energy that the spark is used to remove the metal and acts as a coolant because of the heat generated during the spark [4].

Figure 1: Working principle of EDM [4]

There are many parameters that affect the EDM process. One of these parameters is polarity. The polarity electrode is one of the most important parameters. Polarity can be either positive or negative. The current passing through the gap creates a spark that produces a high temperature causing the material to evaporate in both electrical spots. The polar effect on the cutting process is greatly different where the output (surface roughness, electrode wear ratio, and material removal ratio) varies with the column change process as well as operating time varies when variables and polar differences are proven [5].

M. S. Reza et al. (2010) studied the effect of polarity parameter on machining then concluded that "The negative polarity (tool -, workpiece +) is found optimum for the all analysis on the Material Removal Rate (MRR), Electrode Wear Ratio (EWR) and Surface Roughness (SR) when machining tool steel workpiece using Electric Discharge Machine (EDM)" [6].

S. K. Shatner et al. (2016) improved the surface roughness and metal removal rate during the EDM process by adding Al2O3 and SiC to dielectric solutions respectively using (8,16,30 Am) [7].

A. Begum et al. (2017) studied the effect of polarity on the machining characteristics and surface generation which based on the experimental results, concluded that when the current increases, the metal removal rate, and surface roughness also increases [8].

H.-P. Schulze (2017) studied the importance of polarity change and the polarity effect can be explained very well by the ignition behavior of the spark erosive pulse. The different surface configurations at the electrode and anode base point play a role. The investigation of the same electrode and anode materials shows that the electrical/thermal properties have only an absolute ablation effect. Only in the case of different electrode materials can the advantage of a single-sided higher abrasion be recognized, the electrode ablation being significantly greater than possible anodic applications [9].

1. Experimental Procedures

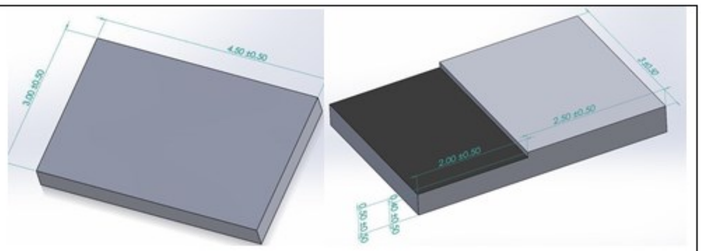
A number of experiments were conducted to study the effects of polarity on surface roughness and metal removal rate. Parameters were used in these experiments (pules on time, polarity and current). The experimental work includes the following steps:

I. Workpiece

The workpiece was used in experiments from Low Carbon steel and its properties are listed in Table 1. Low carbon steel is one of the materials that are used in the formation processes for easy formability where it is considered as a soft metal because of the low ratio of carbon.

Table 1: Chemical composition of the workpiece

Metals	**C%**	**Si%**	**Mn%**	**P%**
Results	0.0895	0.197	0.552	0.0081
Metals	S%	Cr%	Mo%	Al%
Results	0.0043	0.0164	<.002	0.0473
Metals	Ni%	Cu%	Fe%	
Results	0.0282	0.0102	Bal	



a) Workpiece before machining b) Workpiece after machining

Figure 2: Workpiece Low carbon steel

II. Tool (electrode)

The tool was used from copper with characteristics as shown in Table 2.
One of the important factors in the operation of a machine to EDM is the choice of the type of material of the tool. Copper was the best tool material used for the EDM machine (Figure 3).

- Good Electrical and thermal conductivity.
- Low coefficient of thermal expansion.

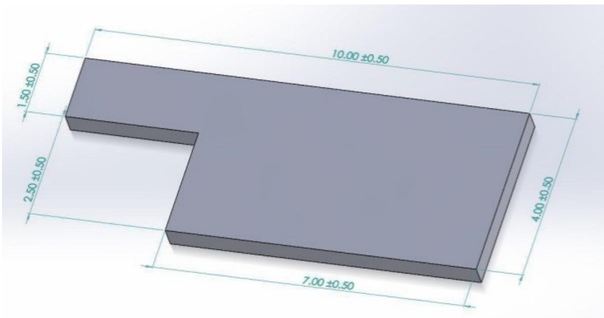


Figure 3: the working tool from copper.

Table 2: properties of copper

Properties	**copper**
phase	solid
Melting point	1084.62˚C
Boiling point	2562˚C
density	8.96 g/cm³
Modulus of elasticity (GPa)	16.5µm/(m.k) (at25˚C)
Thermal conductivity	401 W/(m.k)
Electrical resistivity	1.724×10^{-8} Ω.m

III. EDM machine

The experimental work has been completed on the electro-discharge machining (EDM) machine called CHMER of the model (CM323C). as shown in Figure 4.

Figure 4: EDM machine at U.O.T

IV. Cutting conditions

- **Material Removal Rate (MMR):**

The metal removal ratio is to subtract the weight of the metal before and after the cutting process divided by the time of operation of the piece. Below is the formula to calculate the MRR.

$$MRR = \frac{wb - wa}{tm} \left({}^{g}/_{min} \right) \qquad \text{........ (1)}$$

where:
Wb = weight of workpiece material before machining (g).
Wa = weight of workpiece material after machining (g).
Tm = machining times (min).
The weight of both tool and workpiece is measured before and after the operation with the help of a weighing balance (Denver Instrument). The balance device is shown in Figure 5.

Figure 5: The digital balance instrument

- **Surface Roughness (SR)**

Surface roughness is the irregularity of the surface texture of the sample due to the degree of disparity between high frequencies and short waves. Surface roughness is measured by a roughness measuring device (Maher Federal Company), type (Pocket surfPS1) as shown in Figure 6 and the average is calculated. Ra in µ m unit was used to evaluate the surface roughness.

Figure 6: Surface roughness device

3. Results and Discussion

Table 3 includes the experimental constant parameters and Table 4 includes the results of effect the change of polarity and other parameters (current and T) on the surface roughness (SR), metal removal rate (MRR). MRR depends upon the spark energy; spark energy (Es) is a function of the discharge current. This discharge energy increases as the current is increased and the discharge time increases with the increase in pulse-on time. As shown in the Figures 7 and 8, the metal removal rate increases as the current and pulse-on time of both poles increase. SR depends on discharge energy, so when the current value of both positive pole and negative pole increases, the surface roughness (SR) increases as shown in Figures 9 and 10.

Discussion the best condition for MRR and SR:

The energy at the cathode is greater than the anode, so the positive polarity achieved best (higher) (MRR). While the discharge energy is lower at the negative polarity, this is the reason for the low rate of metal removal when using the negative polarity. The highest values of the rate of metal removal are the best were (0.0180) g/min for positive pole and (0.00291) g/min for negative pole g/min at current = 8 Am and Ton =25 µs. The negative polarity achieves best surface roughness (SR) (lower roughness) than the positive polarity because the discharge energy at the negative polarity is less than the positive polarity and also at the negative polarity of the positive ions have a smaller mass of negative ions so when removing the metal achieve a good surface finish. The low values of surface roughness (best) were (0.46) µm for negative pole and (1.56) µm for positive pole at current = 5 Am, Ton =5.5µs.

Table 3: Experimental Constant parameters

Constant parameters	Parameter values
Pulse off (Toff)	75 µs
High voltage	240 V
Gap voltage code	1mm
Servo feed rate (SVO)	75.0 %
Working time (WT)	1.4sec
Jumping time (JT)	1 mm
Dielectric fluid	transformer oil
Depth of cutting	0.25 mm

Table 4: Results of the experimental work

No. Expt.	Polarity	Current Am	Ton µs	TM (min)	Ra µm	MMR g/min
1	+	5	5.5	49:29	1.56	0.00232
2	+	5	12	36:03	1.83	0.00448
3	+	5	25	17:55	2.47	0.00810
4	+	6	5.5	82:03	1.77	0.00353
5	+	6	12	38:17	2.03	0.00515
6	+	6	25	29:36	2.62	0.0108
7	+	8	5.5	56:47	2.06	0.00561
8	+	8	12	27:35	2.25	0.00984
9	+	8	25	16:18	2.84	0.0180
10	_	5	5.5	299	0.46	0.00054
11	_	5	12	82	0.78	0.00088
12	_	5	25	48:12	1.04	0.00097
13	_	6	5.5	36:33	0.74	0.00116
14	_	6	12	65	0.98	0.00131
15	_	6	25	55:33	1.27	0.00203
16	_	8	5.5	122	0.88	0.00145
17	_	8	12	140	1.08	0.002261

18	_	8	25	33:40	1.66	0.00291

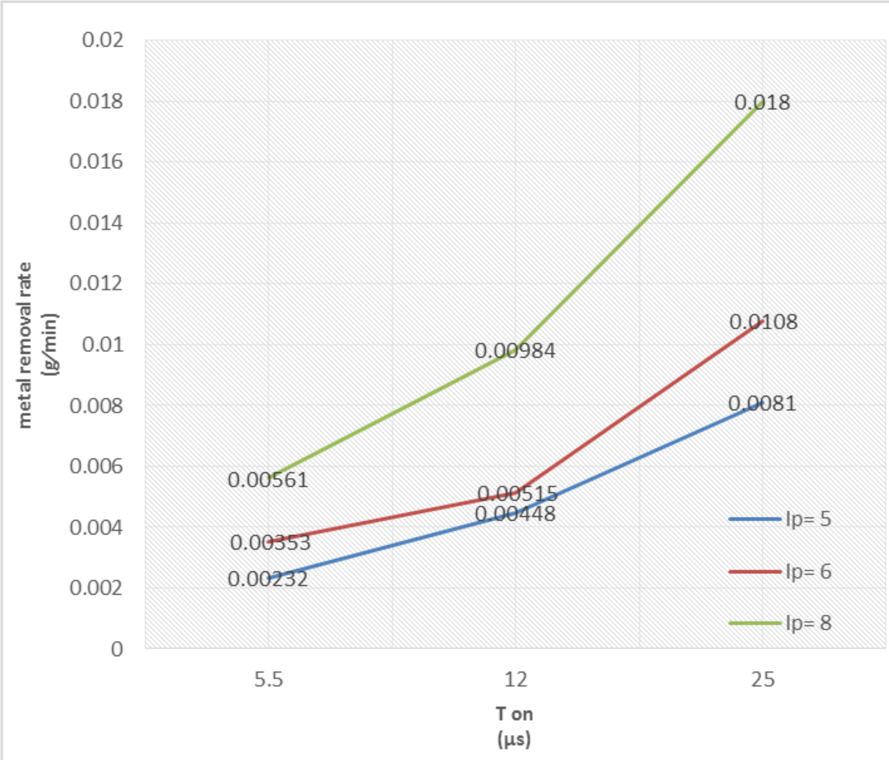


Figure 7: The effect of current and Ton on MRR for positive polarity

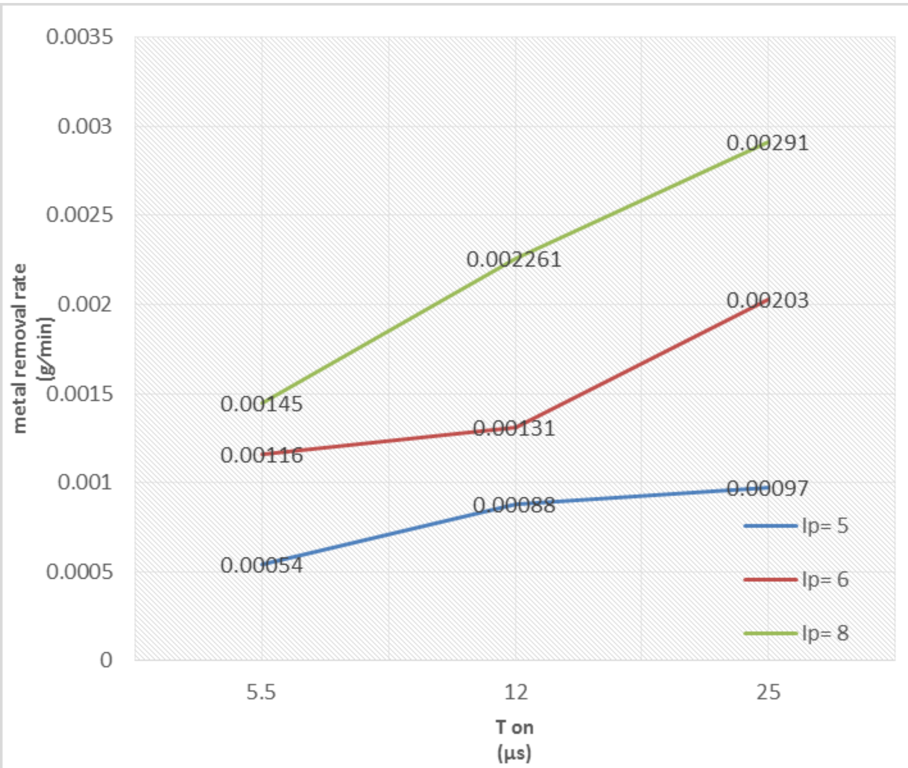


Figure 8: The effect of current and Ton on MRR for negative polarity

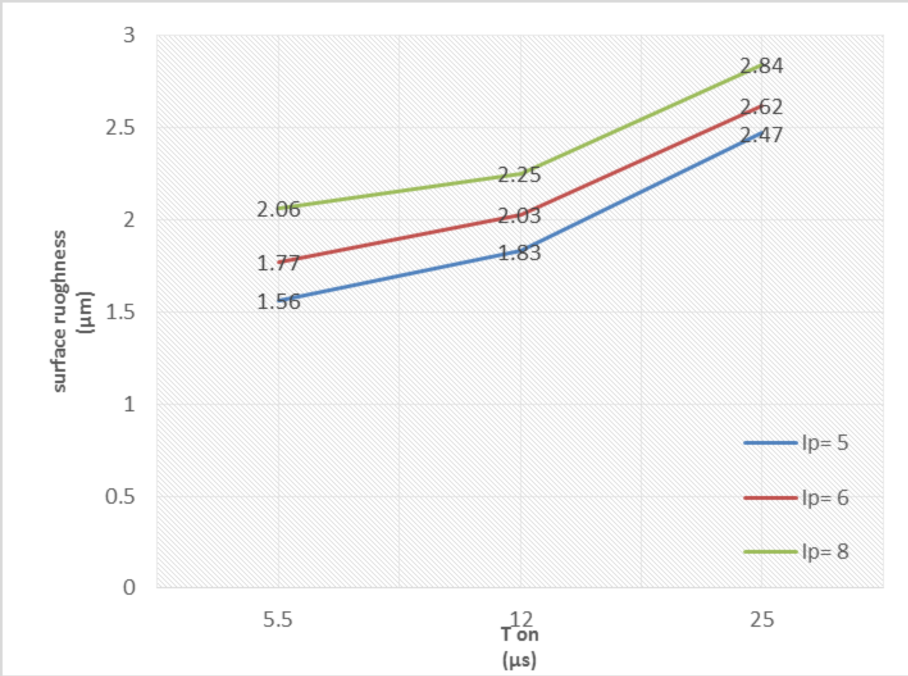


Figure 9: The effect of current and Ton on SR for positive polarity

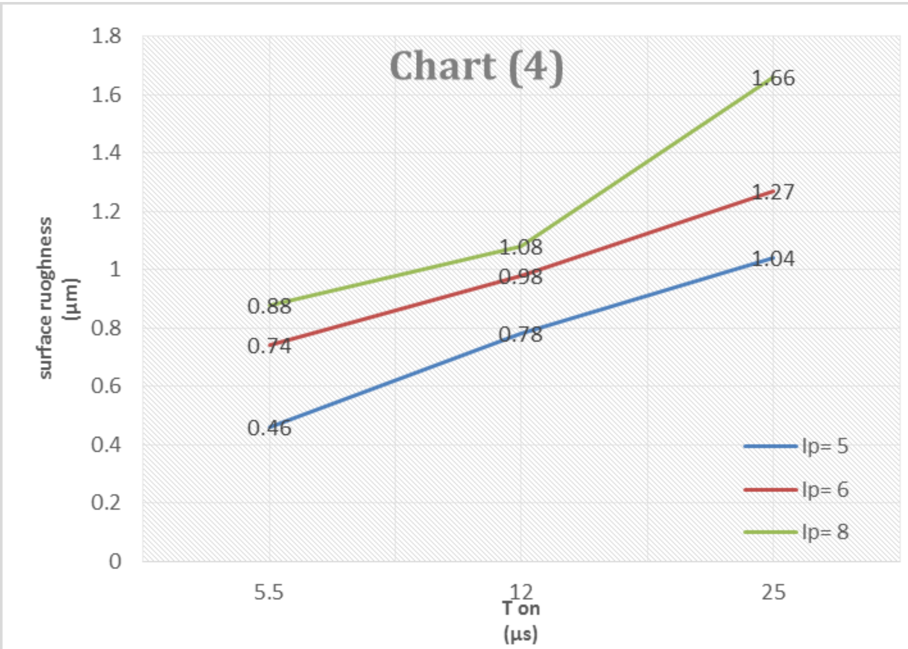


Figure 10: The effect of current and Ton on SR for negative polarity

4. Conclusions

From experiments it can be concluded the following:

i. The metal removal rate (MRR) increasing as the increase of the current and pulse-on time for both positive pole and negative pole.

ii. When the current value of both positive pole and negative pole increases, the surface roughness (SR) increases.

iii. The negative polarity of the tool gives the low value of surface roughness (SR) (the best) and the lowest metal removal rate (MRR), where the best SR (0.46 μm) and the lowest MRR (0.00054 g/min) when the current = 5 Am, Ton = 5.5 μs.

iv. The positive polarity of the tool gives the higher value of MRR (the best) and lowest SR. Where the best MRR (0.0180 g/min) and the lowest SR (0.46 µm) when the current = 8 Am, Ton = 25 µs.

v. The negative polarity of the tool takes more machining time than the positive polarity.

vi. Regardless of the type of polarity used, the highest value is obtained for the rate of metal removal and surface roughness when using the highest value of the current, but this gives the lowest operating time.

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