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Effect of Electro Discharge Machining Process Parameters on Material Removal Rate

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Abstract: **Electro-discharge machining process can be controlled by parameters like pulse on time, voltage and current. Material removal rate is an important parameter to characterize the machining efficiency. Heat generated during Electro-discharge machining depends upon the spark energy, which in turn influences the material removal rate. Important process parameters of EDM are current, voltage and pulse on time. In the present work current, voltage and pulse on time were varied to study the effect of variation in these parameters on material removal rate. MRR increases nonlinearly with the increases in voltage. MRR increases with increase in pulse on time up to a certain limit then decreases. Increase in current provide an initial increase in MRR but further increase in current results in decrease in MRR.**

1. INTRODUCTION

Non-traditional machining processes have been developed since World War II, in which forms of energy other than mechanical energy are utilized. The need for developing most of the process was the search for a better alternative method of machining complex shapes, higher removal of metal from inaccessible places on difficult to machine materials irrespective of hardness limitation. Electro discharge machining process has been proven as an alternative process for machining complex and intricate shapes from all type of conductive materials in which electrical energy is used to cut the material to final shape and size.

1.1. Working Principle of EDM

When a potential difference is applied between the two points of the anode and cathode, cold emission of electron starts. These emitted electrons collide with the dielectric fluid particle and break them into electrons and ions. These liberated electrons again break the particles in electrons and ions and form a channel of plasma. When a discharge takes place, the intense heat is generated this melts and evaporates the material near the sparking zone. For improving the effectiveness, the workpiece and the tool are submerged in the dielectric fluid. It has been observed that if both the electrodes made of the same material, the electrode connected to the positive terminal generally erodes at a faster rate. For this reason, the workpiece is normally made the anode. A suitable gap, known as the spark gap, is maintained between the tool and workpiece surface are the closest and since the spark change after each spark (because of the material removal after each spark),the spark travel all over the surface thus a uniform material removal takes place and finally workpiece get the shape of tool [1].

2. LITERATURE SURVEY

EDM has become now a flexible technology in terms of workpiece hardness, machining rate, complexity of part geometry and surface finish. Die sinking EDM machine can now provide MRR of 245.8 cm^3/hr [2]. Just 35 years ago the wire EDM systems were limited to cutting at about 6.45 cm^3/hr without tapering capabilities [3]. By doing experiment researchers have found out that increasing discharge energy and impulse the MRR increases and surface becomes rougher while layer thickness increases [4]. Influence of pulse current on MRR and surface roughness considering detrimental effect of expansion of plasma arc [5]. Study based on the least squares theory has been carried out which involves establishing the values of the EDM input parameters namely peak current level, pulse-on time and pulse-off time to ensure the simultaneous fulfillment of material removal rate, electrode wear ratio (EWR) and surface roughness (SR)[6]. Importance of MRR in determination of EDM machining performances in terms of efficiency and cost effectiveness has been explored [7].

There is not a monotonous effect of any of the EDM process parameters on MRR. Selection of most favorable process parameters are required for achieving optimal machining performance. Generally these desired process parameters are determined based on experiences which comes from experimental study on EDM. The present study was carried out using die sinking EDM machine and it was found that besides the aforesaid process parameters, simultaneously MRR also depends on other factors like flushing condition, clamping and positioning of workpiece in die and tool in tool holder.

3. EXPERIMENTAL DETAILS

3.1. Workpiece

A cubical piece of (35 mm x 15 mm x10 mm) of mild steel has been used as a workpiece material for the current experiment. Workpiece is carefully kept to avoid rusting. Percentage chemical composition of workpiece is as follow-C - 2.20, Si – 0.696, Mn – 0.406, P- 0.04, Cr – 13.1, Mo – 0.0742, Ni- 0.044, Cu-0.0613, remaining is Fe.

3.2. Tool

For preparing the tool, a copper piece of rectangular cross-section (40mm x 20mm) was cut, A hole was drilled at the centre of surface up to certain depth on one side of tool and then tapping was done for tightening the tool with tool shank which is clamped in EDM tool holder.

3.3. Calculation of MRR

MRR is the rate at which the material is removed from the work piece. Its unit is mm^3/s. The material is removed from the work piece because of series of recurring spark between the two electrodes.

$MRR = (W_i - W_f) / t \times \rho$
Where, W_i = initial weight of material
W_f = final weight of material after experiment
t = machining time = 10 min
ρ = density of material = 7.84 gm/cc^3

The MRR can be defined as the rate of material removed per second or the ratio of change in volume of workpiece during machining divided by duration of machining.

Since for each and every experiment, t and ρ have been kept constant and weight loss is only varying quantity with respect to various EDM process parameters. That's why MRR has been expressed in terms of weight loss in gram.

3.4. Calculation of spark energy

Evaluation of spark energy is important due to melting and evaporation of workpiece material and outcome of machining on surface roughness, microstructure, microhardness, and heat affected zone (HAZ) .Following equation was used for calculating the spark energy.
Spark Energy (joule)= $I_d \times V_g \times T_{on}$

3.5. Machine tool

The whole experiment has been conducted on a Z numerically controlled (ZNC), oil die-sinking EDM machine, (R50#ZNC) with MOSFET pulse type generator. The smart ZNC EDM machine is manufactured by Electronica Machine Tools Ltd.

3.6. Weighing of specimen

Electronic balance was used for weighing the workpiece and tool, before and after machining. It had a weighting capacity of 210 grams and can accurately measure the weight of 0.001 gram.

3.7 Condition of EDM Process

Table 1 shows the details of experimental conditions used in the present study.

Table 1. Experimental conditions

S.No.	Parameters	Details
1	T_{on} (μs)	10, 50, 100, 200
2	Discharge current (Amp.)	4, 5, 6, 7
3	Voltage (V)	5, 10, 15, 20
4	Dielectric	EDM oil servo 40
5	Machining time (minutes)	10
6	Polarity	Straight

4. RESULT AND DISCUSSION

In present work, effect of different EDM parameters on MRR and spark energy has been discussed .Three different process parameters, namely T_{on}, Ip and Vg have been used at four different levels to study the effect in variation of parameters on material removal rate and spark energy. It has been ascertained that flushing serves to remove the eroded solid debris and gaseous product from the spark gap region during machining operation and also to maintain the dielectric temperature well below the flash point. Therefore, flushing pressure is selected carefully so that proper flushing could be accomplished from between the spark gap. Table 2 represents the loss in weight of workpiece material while machining with copper tool at various parameters.

Table 2. Reduction in weight of workpiece at various parameters

Parameters		Initial wt.(gm)	Final wt.(gm)	Weight loss(gm)
T_{on} (μs)	10	44.0322	43.9399	0.0923
	50	43.9399	43.6107	0.3292
	100	43.6107	43.1983	0.4124
	200	43.1983	42.7983	0.4000
Current (Amp.)	4	45.7076	45.5790	0.1286
	5	45.5790	45.4399	0.1391
	6	45.4399	45.3052	0.1347
	7	45.3052	45.2167	0.0885
Voltage (V)	5	44.8303	44.7154	0.1149
	10	44.7154	44.5985	0.1169
	15	44.5985	44.4771	0.1214
	20	44.4771	44.3487	0.1284

4.1. Effect of pulse on time (T_{on}) on MRR and spark energy

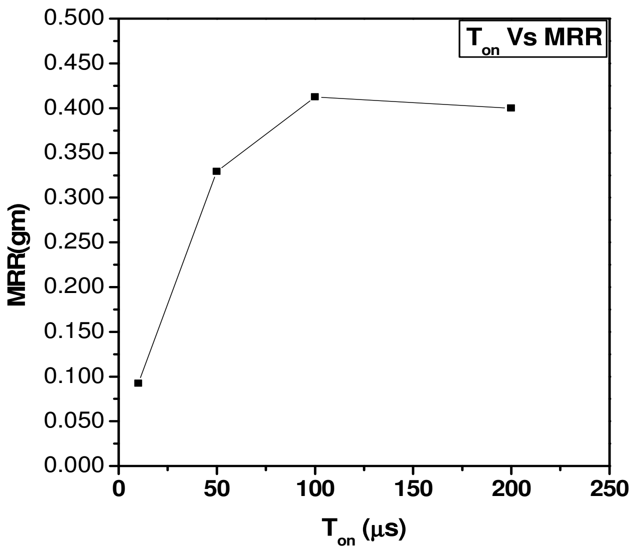

Fig. 1. Variation of MRR with pulse on time

A non linear relationship between pulse on time and MRR has been observed as shown in fig.1. MRR increases as the value of T_{on} increases up to 100 µs. The rate of increase in value of MRR is more for range of Ton (10µs -50µs) than range of (50µs- 100µs). With further increase in pulse on-time from 100 µs -200 µs, the MRR decreases slightly. This may be attributed to reason that with high pulse on time i.e. 200µs, more material gets melted at the tool workpiece interface, which require proper flushing time but as the value of pulse off time is too short comparative to pulse on time so there is not enough time for the flushing to clear the debris from the inter-electrode gap between the tool and work piece, hence arcing takes place which accounts for decreasing the MRR.

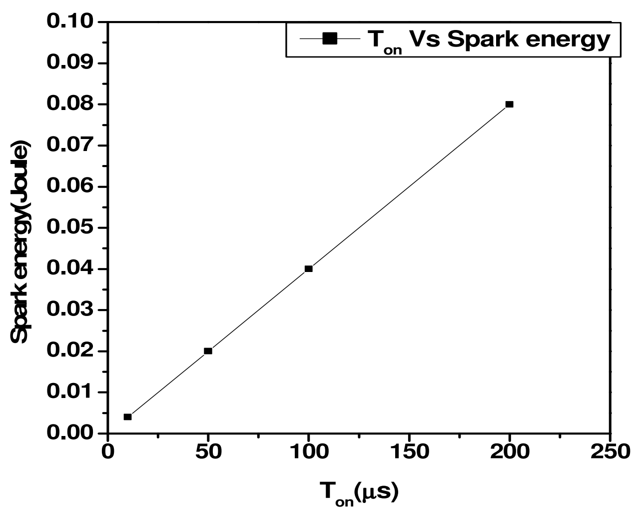

Fig. 2. Variation of spark energy w. r. t. pulse on time

Figure 2 shows a linearly increasing trend between pulse on time and spark energy. It may be noticed that rate of increase in spark energy is nearly uniform as the Ton increases.

4.2. Effect of current on MRR and spark energy

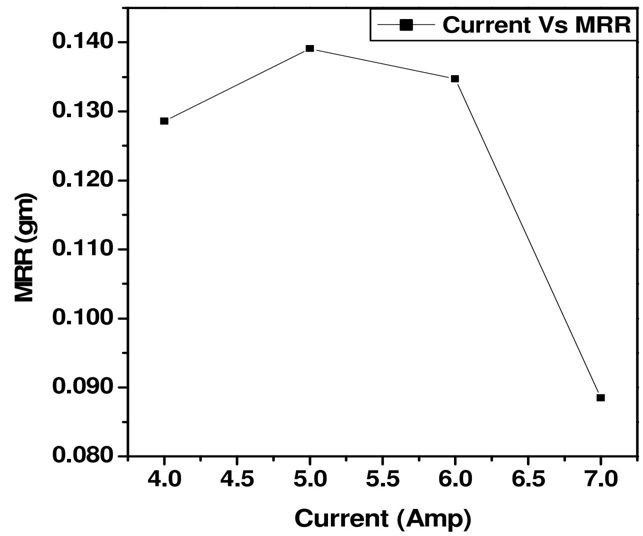

Fig. 3. Variation of MRR w. r. t. current

It was observed that MRR was mostly affected by current as indicated in Fig. 3. In the range (4 amp-5 amp), MRR increases moderately then it decreases slightly between (5amp-6 amp) and finally it MRR decreases sharply in the range(6amp-7 amp). Decrease in MRR is be due to the contamination of plasma column in gap. This contamination is caused by debris (dislodge material) from electrodes.

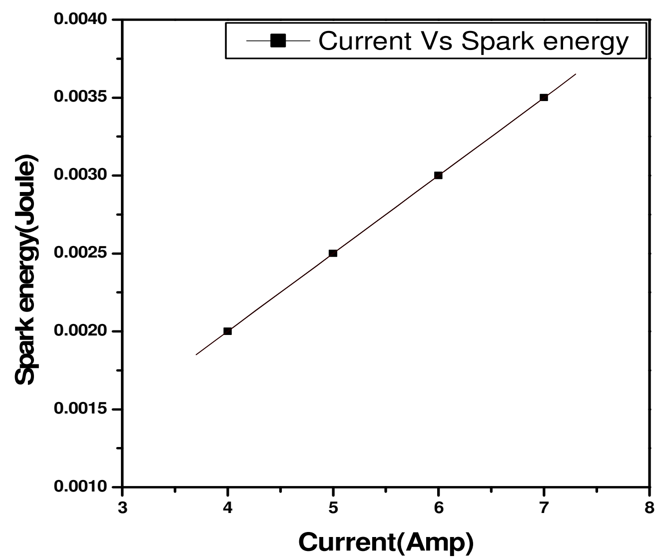

Fig. 4. Variation of spark energy w. r. t current

Spark energy is directly proportional to applied current as depicted in Fig. 4.

4.3 Effect of Voltage on MRR and spark energy

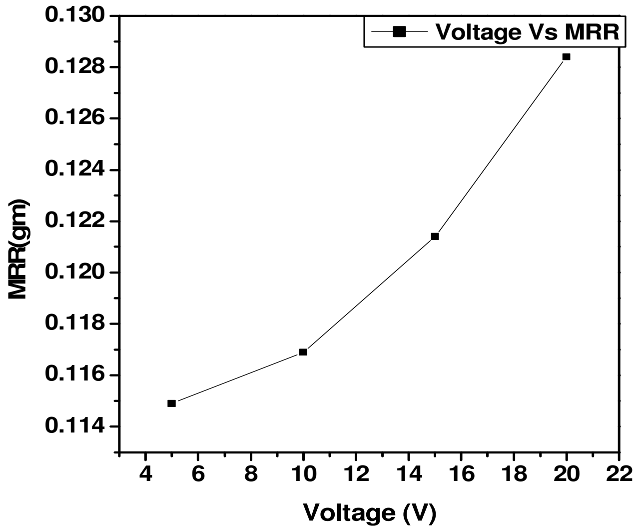

Fig. 5. Variation of MRR w. r. t. Voltage

Figure 5 represents variation of MRR w.r.t. voltage. There is slight increase MRR from 5 V to 10 V and sharp decrease from 15 V to 20 V. Decrease in MRR with increase in voltage lies between above two in range of (10 V- 15 V). Increase in voltage leads to increase in spark energy. More spark energy means more material removal in the presence of suitable values of remaining process parameters.

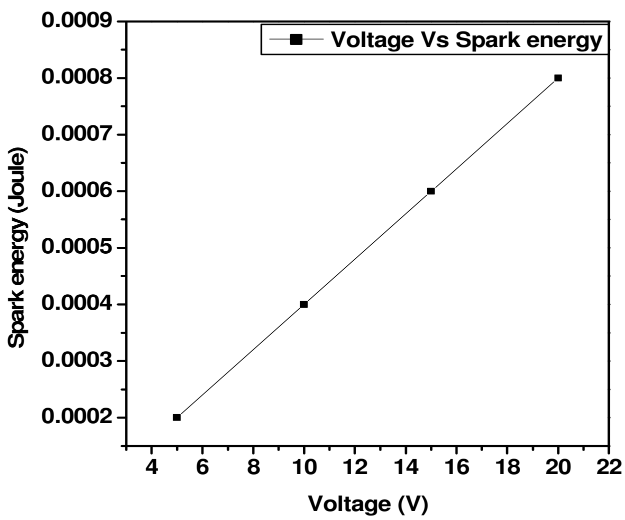

Fig. 6. Variation in spark energy w. r. t. voltage

Figure 6 shows the similar relationship between voltage and spark energy as current/Ton Vs spark energy. From figures 4.2, 4.4 and 4.6, it can be concluded that spark energy is function of pulse on time, current and voltage and also linearly dependent on these EDM parameter.

5. CONCLUSIONS

From the present study, following major conclusions can be drawn.

- EDM Process parameters namely pulse on time, current and voltage affect the material removal rate.
- MRR increases with increase in pulse on time up to a certain then decreases.
- Increase in current provide an initial increase in MRR but further increase in current results in decrease in MRR.
- MRR increases with increase in voltage.
- Spark energy was found to affect MRR.

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