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EFFECT OF FLUSHING CONDITIONS ON MATERIAL REMOVAL RATE IN EDM

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ABSTRACT

This paper is focused on the comparative study of process control variables on Material removal rate under side and centre flushing conditions in EDM. In this research, one variable at a time methodology is adopted to investigate the effect of six control variables namely current, voltage, spark gap, Ton, duty cycle, and flushing pressure, on material removal rate (MRR) in Electrical Discharge machining (EDM). The experiments were conducted on round copper tools of EN 31 with kerosene as dielectric under center flushing & side flushing conditions. The results indicate that machining parameters and flushing conditions have significant effects on Material Removal Rate (MRR).

Keywords: *Electric Discharge Machining (EDM), Material Removal Rate, Ton, Duty Cycle, Flushing Condition.*

1. Introduction

Even after 66 years of EDM, researchers are still struggling to achieve increased material removal rate to meet the industrial demand. Electric discharge machining (EDM) is a manufacturing method used to machine hard materials in complex shapes with high precision. The process has drawn a great deal of researchers' attention because of its broad industrial applications [1]. Since it is a costly process, optimal settings of the process parameters are utmost important to reduce the machining time and to enhance the productivity [2]. In EDM process material is removed by a succession of electrical discharges occurring between an electrode and work-piece both submerged in a dielectric bath, such as kerosene and distilled water [3]. It is extensively used in machining of high strength temperature-resistant materials like high strength steel, tungsten carbide, hardened steel and alloys which are widely used in aerospace, automotive and die industries. In this process material is removed by controlled erosion through a series of electric spark discharges across the gap between electrode (tool) and the work-piece as shown in Fig. 1. In a complete EDM process, machining stages that include rough cut, middle cut and finish cut, are carried out sequentially. The thermal energy of the sparks leads to intense heat conditions on the work-piece causing melting and vaporization of work-piece material [4].

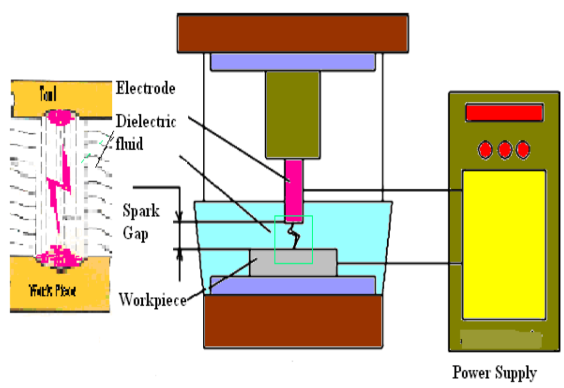

Fig. 1 Systematic Line Diagram of EDM Process

Due to high temperature of sparks, not only work-piece material is melted and vaporized, but electrode material is also melted and vaporized, which is known as electrode wear (EW). The EW process is quite similar to the material removal mechanism in EDM [5], which causes the inaccuracy due to the dimensional loss of the tool electrode. So it is desirable to obtain maximum material removal rate (MRR) with minimum electrode wear. The process parameters varied in the different machining stages of EDM process greatly affect the machining performances. Subsequently, it becomes important to select properly the process parameter set for different machining stages in order to promote efficiency [6].

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In recent years, many attempts have been made for modeling the EDM process and investigation of the process performance to recuperate MRR [2, 7, 9]. Improving the MRR and surface quality are still challenging problems that restrict the expanded applications of the technology [8]. Semi-empirical models of MRR for various work-piece and tool electrode combinations have been presented by Wang and Tsai [9]. Usually the desired process parameters are determined based on experience or hand-data-book values. However, it is undoubtedly a challenge to ensure that the selected process parameters result in optimal or near optimal machining performance for that particular EDM and environment. In this research, one variable at a time methodology of experimentation is adopted to investigate the effect of process variables (current, voltage, spark gap, T_{on}, duty cycle, and Flushing pressure) on material removal rate in electrical discharge machining. The experiments were conducted on round copper tools of EN 31 with kerosene as dielectric under center flushing & side flushing conditions.

2. Material Removal Rate

A power supply delivers high-frequency electric pulses to the tool and the work-piece in EDM. A stream of dielectric liquid is flushed through the electrode and work-piece. The insulating property of the dielectric fluid is momentarily broken down as an electric pulse is delivered from the power supply which causes a small spark to jump the shortest distance between the tool and work-piece. This results in formation of a small pool of molten metal on the work-piece and the tool at the point of discharge. A gas bubble forms around the discharge and the molten pool. As the electric pulse ceases and the discharge disappears, the gas bubble collapses. The surge of cool dielectric causes the molten metal to be ejected from the work-piece and the tool, leaving small craters. This action is repeated thousands of times each second during EDM processing and removes material from the work-piece in a shape complementary to that of the tool. It also removes some of the material from the tool electrode thus affecting the machining accuracy.

The material removal rate is calculated by ratio of volumetric material removal from the work piece to machining time. It is expressed as,

$$MRR = \frac{V_W}{T_m} \quad (1)$$

Where V_W is volumetric material removed from the work-piece (mm^3) and T_m is machining time (min).

Normally, the material removal rate is determined by weight difference of sample just before and after being subjected to the EDM process. Many investigations have been conducted on MRR in EDM process. An experimental analysis is performed to determine MRR & EW ratio in EDM with high carbon steel [10] and during the machining process it was observed that a black layer of carbon was formed on the surface of the electrode, which prevented the electrode from being eroded. It indicates that the EW ratio was strongly associated with carbon film. Luis et al. [8] designed and developed models for MRR and EW using the design of experiment (DOE) method and multiple regression analysis considering generator intensity (I), Pulse time, duty cycle, and dielectric parameters as input parameters and the MRR and EW as responses

3. Experimental Set Up

The electric discharge machine used in this investigation was Electra R 50 Model die sinking machine. Kerosene dielectric was used in the experiment. Fig. 2 shows a machining setup.

Fig. 2 Experimental Set up

3.1 Preparation of work piece

Work-piece specimens of diameter 22mm & length 30mm were cut from EN-31 steel bar. Both the surfaces of the specimens were made parallel & ground and hardened to HRC 48 using salt bath hardening method. Fig. 4 shows the specimens. Work piece is prepared for two set of experiments. One with centre hole (through) of diameter 3mm for experimental setup with centre flushing, hole is made before hardening, and the other is without centre hole for experimental set with side flushing.

Fig. 3 Different Specimens Ready for Machining

3.2 Preparation of electrode

Similarly two set of tools (electrode) were prepared, with centre through hole of 3mm diameter for centre flushing and without hole for side flushing. Electrode was prepared by cutting round copper rod of 22mm diameter and 30 mm length. The electrodes were turned to 20mm diameter and end surfaces were made parallel and ground.

3.3 Machining parameters

For both the set of experiments, controlled process parameters are kept same as current (i_e) of 4, 6, 8, 10, 12A , Voltage (V) 30, 35, 40, 45, 50V, spark gap 0.3, 0.4, 0.5, 0.6, 0.7mm, Pulse on time (ton) 50, 100, 150, 200, 500μs, pulse off time (Duty Cycle) 6, 7, 8, 9, 10 μs , flushing pressure 0.2, 0.4, 0.6, 0.8, 1.0 bar. Both centre flushing (injection flushing) and side flushing were used to investigate the effect of flushing , current, voltage, spark gap, pulse on time, and pulse off time on MRR using one variable at- a- time approach. Each experiment was repeated thrice and average of the three values of measurements was used to calculate material removal rate keeping machining time as 12 minutes.

3.4 Determination of material removal rate

Weight loss of the work-piece was calculated by weighing the initial and final (after machining) weights of the work-piece by using digital scale (China make) with .001g accuracy. The machining time (tm), was measured by a stop watch and material removal rate was determined by taking ratio of material loss and machining time.

4. Experimental Results and Discussion

4.1 MRR comparison experiments

The centre flushing and side flushing methods are used in the experiments keeping the process parameters same during both the setups and the comparisons are shown in Figures 4 to 9.

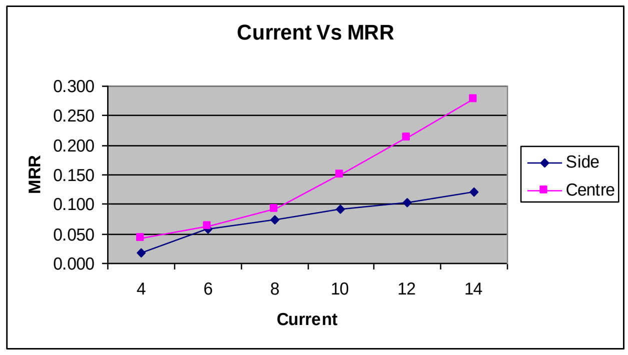

Fig. 4 Effect of Current on MRR

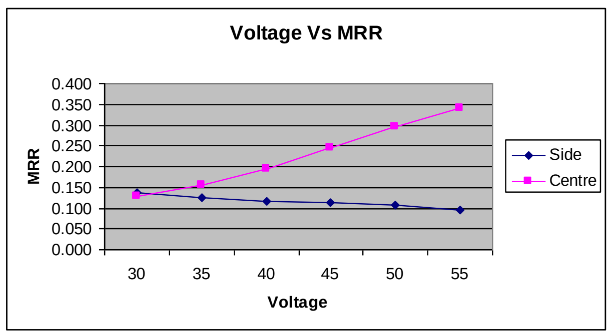

Fig. 5 Effect of Voltage on MRR

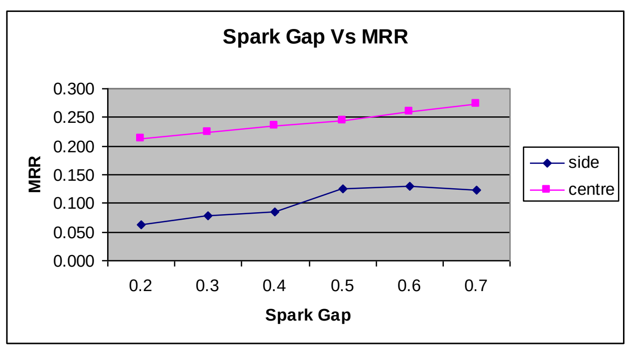

Fig. 6 Effect of Spark Gap on MRR

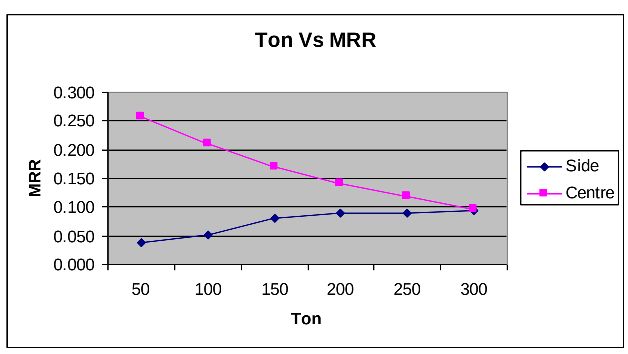

Fig. 7 Effect of T_{on} on MRR

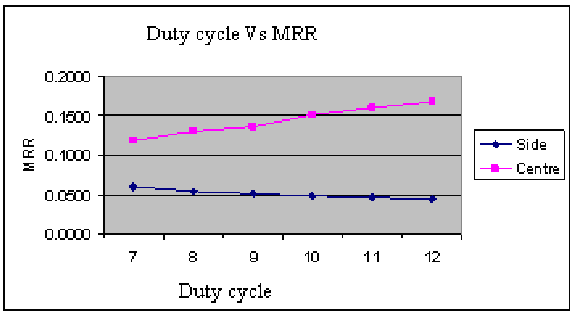

Fig. 8 Effect of Duty Cycle on MRR

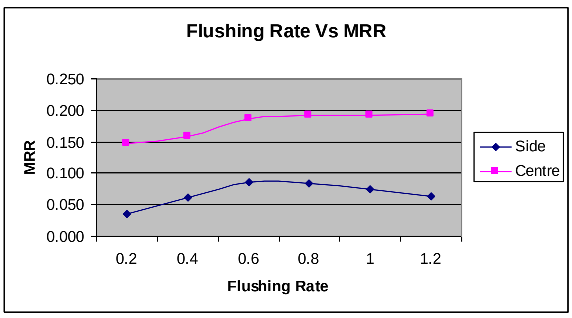

Fig. 9 Effect of Flushing Pressure on MRR

4.2 Results and discussion

The results are shown graphically in Figures 4 - 9. From Fig. 4, it can be seen that the Material Removal Rate (MRR) shows significant increase with increase in current in both the cases (centre flushing and side flushing). It is observed that material removal rate is approximately 3 times higher in centre flushing as compared to side flushing at higher values of current. Fig. 5 shows that MRR increases with increase in voltage in centre flushing, while there is negligible decrease in MRR with increase in voltage in side flushing.

From Fig. 6 it can be observed that MRR is approximately twice in centre flushing as compared to side flushing with change in spark gap. Fig. 7 reveals that MRR decreases with increase in Ton in centre flushing where as a little increase in MRR is observed in side flushing with increase in Ton. From Fig. 8 it can be seen that MRR increases with increase in Duty Cycle in center flushing while in side flushing MRR decreases with increase in Duty Cycle values. Fig. 9 reveals that MRR in case of centre flushing first increases with increase in flushing pressure, attains maximum value and then decreases with further increase in the flushing pressure. The Fig. 9 also shows that material removal rate increases with flushing pressure in side flushing upto a value and then it remains almost constant for increasing values of flushing pressure.

5. Conclusion

The effects of various parameters like current, voltage, spark gap, Ton, Duty Cycle, flushing rate, and flushing methods on Material Removal Rate are investigated through experimentation. The following conclusions can be drawn:

i. The Material Removal Rate increases with the increase in current and spark gap.
ii. Material Removal rate is higher in centre flushing as compared to side flushing.
iii. In centre flushing MRR increases significantly with increase in voltage while it decreases negligibly with increase in voltage.
iv. Material Removal Rate decreases significantly with increase in Ton in centre flushing while a small increase in MRR is observed with increase in Ton with side flushing

From discussions it can be concluded that centre flushing has more significant effect on MRR as compared to side flushing under various conditions of control parameters. This is owing to the fact that proper flushing effect cannot take place in side flushing.

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