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EFFECT OF SIZE AND SHAPE OF ELECTRODES ON THE PERFORMANCE OF EDM

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ABSTRACT

In the present study the effect of size and different shapes of electrodes on material removal rate (MRR), job surface finish and wear ratio (WR) during EDM has been investigated. The work material taken was mild steel and the electrode material taken was copper. The size of the electrodes was 9mm, 15 mm, 20 mm and 30 mm in diameter. The shapes of the electrodes were square, round, triangular and diamond, having the same area of cross-section. The highest MRR was found for round electrodes followed by square, triangular and diamond shaped electrodes. MRR was found to increases sharply with the increase in diameter of the electrodes. With increase in current, the sparks produced are of higher thermal energy. As a result, increase in current resulted increase in MRR. A higher thermal energy also erodes more material from the electrode. Electrode wear (EW) was measured along the cross-section of the electrode as well as along its length. EW was also found to increase with the increase in current. However, the highest EW was fond on the diamond shaped electrodes followed by triangular, square and the round shaped ones. An electrode of smaller cross-section exhibited a higher electrode wear. Wear ratio (WR) was calculated as the ratio of the volume of material removed from the electrode to the same removed from the work material. The highest WR was found on the diamond shaped electrodes followed by triangular, square and round electrodes. It was also found that WR decreases with increase in cross-sectional area of the electrode. Job surface roughness was found to decrease with increase in electrode diameter, but the effect is very insignificant. The smoothest job surface finish was found for round electrodes followed by square, triangular and diamond shaped electrodes. But again, the influence of the shape of the electrodes on job surface finish was found to be insignificant.

KEY WORDS:

EDM, Material removal rate, Electrode wear, Size and shape of electrodes, Surface roughness.

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INTRODUCTION

In electrical discharge machining (EDM) material is removed by a series of electrical discharge between the electrode and the workpiece that develops a temperature of 8,000 °C to 12,000 °C. The unique feature of using thermal energy to machine electrically conductive parts regardless of their hardness has been EDM's distinctive advantage in the manufacture of mould, die, automotive, aerospace and surgical components.

Due to high temperature of the sparks, not only work material is melted and vaporized, but the electrode material is also melted and vaporized, which is known as electrode wear (EW). EW process is quite similar to the material removal mechanism as the electrode and the workpiece are considered as a set of electrodes in EDM [1]. Due to this wear, electrodes loose their dimensions resulting inaccuracy of the cavities formed [2]. The performance of EDM is evaluated by the output parameters like material removal rate (MRR), EW, wear ratio (WR) and job surface finish [3, 4]. It is desirable to obtain maximum MRR with a little EW. Electrodes are made of wide varieties of materials. The common electrode materials are graphite, brass, copper and copper-tungsten alloys [5, 6]. Efforts have been done to minimize electrode wear. A metal matrix composite (ZrB_2-Cu) was developed adding different amount of Cu to get an optimum combination of wear resistance, electrical and thermal conductivity [7]. It was reported that ZrB_2-40 wt% Cu composite shows more MRR with less EW. Manufacturing of electrodes of special composition is expensive and not always cost effective. Research works have been conducted to draw the relationship of MRR with current, voltage, pulse duration, etc [8]. In order to maintain the accuracy of machining, electrode wear compensation has been reported to be an effective technique, where wear was continuously evaluated by sensors and the compensation was made [9]. Some researchers have tried to develop mathematical models to optimize the EW and MRR [10, 11]. It was reported that MRR can be substantially increased with reduced electrode wear using a multi-electrode discharging system [12]. But again, manufacture of special electrodes involves additional cost. In the present study experimental investigations has been carried out to determine the relationship of EW, MRR and surface finish with the size and shape of the electrodes.

EXPERIMENTAL PROCEDURE

Materials

In the present study the work material used was mild steel and the electrode material used was copper. The chemical composition and physical properties of the work material is shown in Table 1 and Table 2 respectively. The major properties of copper are shown in Table 3. All the electrodes used were 80 mm long. In order to investigate the influence of diameter of the electrode on the EDM performance, electrodes were made with diameters of 9 mm, 15 mm, 20 mm and 30 mm. In order to investigate the shape of electrodes on the EDM performance, electrodes were prepared with round, square, triangular and diamond shaped having the same cross-sectional area as shown in Fig.1.

Experimental Procedure

Mitsubishi EX22 model CIIE FP60E die sinking machine was used for conducting the experimental works. During the experimental works the voltage, spark on-time and duty cycle were kept constant at 10 V, 5.5 s and 52.4% respectively. The currents tried were 2.5 amps, 3.5 amps and 6.5 amps. The depth of the machined cavities was 2 mm. The time required to machine each cavity was recorded. The weight of the workpiece and the electrode were measured before and after each machining operation. Difference of the weights of the workpiece before and after machining gives the material removed from the work and the difference of weights of an electrode before and after machining gives the material eroded from the electrode. WR was calculated as the ratio of material removed from the electrode to the same removed from the work. Corner wear of the electrodes along its length and cross-section was measured using JOEL scanning electron microscope model JSM 56000. The work surface roughness was measured using Mitutpyo SURFTEST SV-500.

RESULTS AND DISCUSSIONS

Material Removal Rate

Material removal rate of electrodes different sizes at different currents are shown in Fig.2. With the change of diameter of the electrode from 9 mm to 30 mm, MRR increases to 6.67%. An electrode with a higher diameter has a larger cross-sectional area than an electrode with a lower diameter. As a result, heat energy per unit are of the electrode is lower and consequently the temperature difference between the machining zone and surrounding is also lower. This results less heat loss in the surrounding and more MRR. However, it is obvious that MRR increased significantly with increase in current. A higher current will produce a stronger spark with higher thermal energy that results more MRR [2].

Figure 3 illustrates the influence of the shape of the electrode on MRR at different currents. The highest MRR was found for round electrodes followed by square, triangular and diamond shaped electrodes. It can be noted hare that all the electrodes had the same cross-sectional area of 64 mm^2. Consequently, the peripheral length of the round, square, triangular and diamond shapes electrodes are 28.27 mm, 32 mm, 36.47 mm and 45.25 mm respectively. Diamond shaped electrodes had the largest peripheral area that allowed faster heat loss to the surroundings. As a result, less heat is available for material removal compared to the other electrodes.

Electrode Wear

EW results inaccuracy of the shape and size of the cavity machined by EDM. Ahsan [13] found that electrode wear along the cross-section of the tool is more compared to the same along the length of the electrode. The later can be compensated by additional vertical feed of the electrode, but the wear along the cross-section of the tool cannot be compensated and results inaccuracy of the machined cavity. EW along the cross-section of round shaped electrodes is shown in Fig.4. EW reduces with increase in diameter of the electrode. At a current of 2.5 amps, EW with diameters 9 mm and 30 mm are 470 µm and 333 µm respectively. The heat energy per unit area of a smaller electrode is higher than that of an electrode of larger cross-sectional area under the same machining conditions. Consequently, more melting and vaporization result on the electrode of a smaller cross-section. SEM views of corner wear of electrodes (Fig.5 and Fig.6) for diameters of 20 mm and 30 mm respectively under the same machining conditions (current 2.5 Amps) show that an electrode of a smaller diameter undergoes comparatively more wear.

EW along the cross-section of different shapes is illustrated in Fig.7. The maximum wear was observed for diamond shaped electrodes followed by triangular, square and round shaped electrodes. Sharper angles of diamond shaped electrodes causes high heat concentration resulting more electrode melting and vaporization. Again, Fig.8 and Fig.9 for corner wear of round and a diamond shaped electrodes (having the same cross-sectional area) demonstrate an intensive wear of diamond shaped electrodes compared to the round shaped one.

Wear Ratio

WR is calculated as the ratio of the volume of material removed from the electrode to the same removed from the work material. Fig.10 shows that WR decreases with increase in diameter of the electrode and increases with the increase of current. It indicates that electrodes undergo more wear compared to the workpiece when their diameter is small. Usually the workpiece is a massive one compared to the electrode and heat can easily be dissipated into the body of the workpiece. But heat transfer through an electrode of a slammer diameter is poorer that results more melting and erosion of the electrode. Thus, WR of electrodes with diameters 30 mm and 9 mm are 0.11 and 0.23 respectively.

Influence of the shape of electrodes on WR is illustrated in Fig.11. At any machining parameter the highest WR was fond for the diamond shaped electrode followed by the triangular, square and the round shaped electrodes. At a current of 6.5 amps, the WR of a diamond shaped electrode is 1.7 times to that of a round shaped electrode.

Surface Roughness

The work surface finish produced by electrodes of different diameters is illustrated in Fig. 12. It is evident that the influence of electrode diameter on work surface finish is insignificant. However, an electrode of larger diameter produces a smoother surface. Heat input per unit area of an electrode of a smaller diameter is higher than that of an electrode of larger diameter. Higher heat input produces deeper craters on the surface making the surface rougher.

Figure 13 shows that surface roughness sharply increases with increase in current. A higher current produces a stronger spark making a deeper cavity. Consequently the surface becomes rougher. The rougher surface was produced by the diamond shaped electrode followed by the triangular, square and round shaped electrode. Temperature distribution along the cross-section of a round shaped electrode is more uniform than electrodes of other shapes. This results more uniform material removal and the surface produced is comparatively smoother. However, the influence of electrode shape on surface roughness in not significant.

CONCLUSIONS

1. MRR increases with increase of the diameter of the electrode. The temperature difference between the machining zone and the surrounding is less while using an electrode of larger diameter compared to the same while using an electrode of a smaller diameter. This results in less heat loss and increased MRR.
2. For round shaped electrodes MRR was the maximum followed by the square, triangular and the diamond shaped electrodes having the same cross-sectional area. Diamond shaped electrode has the largest peripheral area compared to the other electrodes resulting more heat loss to the surrounding.
3. Under the same machining conditions the wear of an electrode of smaller diameter is higher than that of an electrode of larger diameter. A round shaped electrode undergoes less wear followed by the square, triangular and the diamond shaped electrodes.
4. WR decreases with increase in diameter of the electrode. It indicates that an electrode of a smaller diameter undergoes more wear compared to the work material. Again, WR was highest for the diamond shaped electrode followed by the triangular, square and the round shaped electrodes.
5. The influence of the size and shape of electrodes on surface finish is insignificant. However, an electrode of larger diameter produces a smoother surface. Again, a round shape electrode produces a smoother surface followed by the square, triangular and the diamond shaped electrodes.

ACKNOWLEDGEMENT

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Tables and Figures

Table 1: Chemical composition of work material

Work materials	Chemical composition
Mild steel	C: 0.14%-0.2%, Fe: 98.81-99.26%, Mn: 0.6%-0.9%, P: 0.04%, S: 0.05%

Table 2: Physical properties of work material

Work materials	Thermal conductivity (W/m-^{o}K)	Melting point (^{o}C)	Electrical resistivity (ohm-cm)	Specific heat capacity (J/g-^{o}C)	Hardness (HB)	Tensile strength (MPa)	Yield strength (MPa)
Mild steel	51.9	1523	1.74	0.472	143	475	275

Table 3: Physical properties of copper

Work material	Thermal conductivity (W/m-^{o}K)	Melting point (^{o}C)	Electrical resistivity (ohm-cm)	Specific heat capacity (J/g-^{o}C)
Copper	391	1,083	1.69	0.385

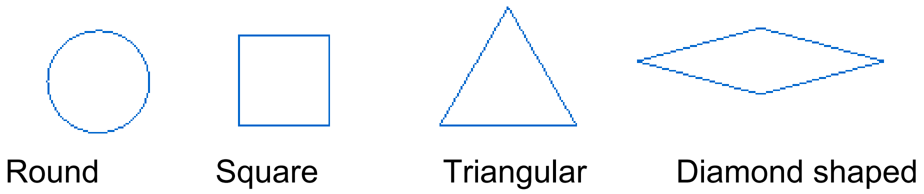

Fig.1: Electrodes of different shapes

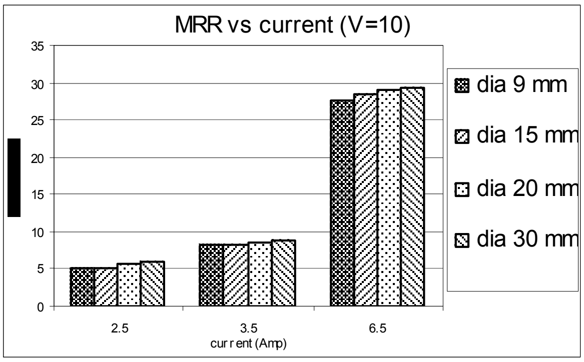

Figure 2: MRR for different diameters (10V)

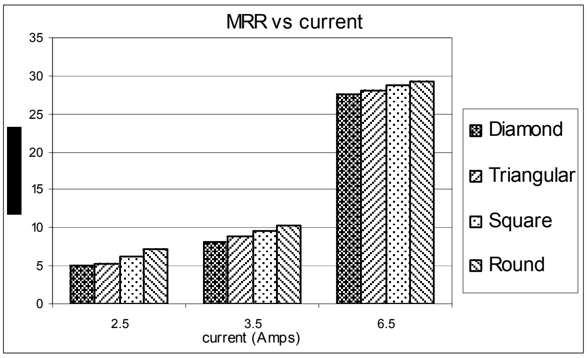

Figure 3: MRR for different shapes (10V)

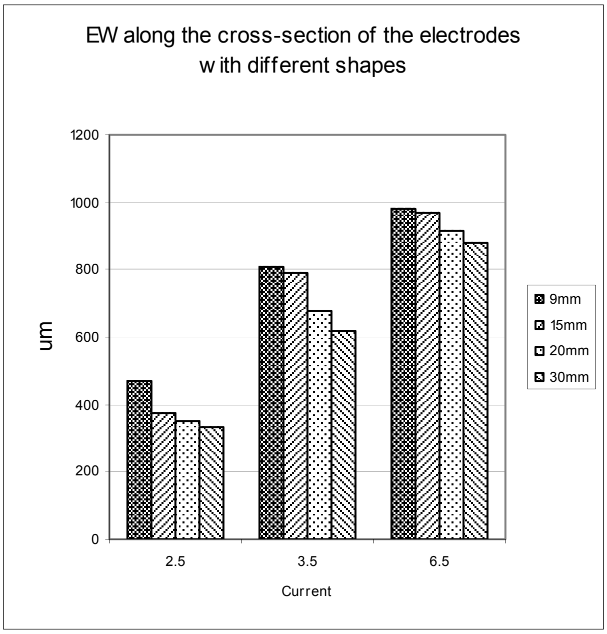

Figure 4: EW along the cross-section for different diameters (10V)

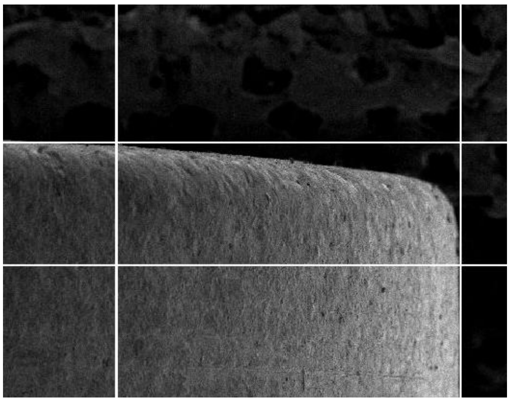

Fig. 5: Diameter 20mm; current 2.5 A

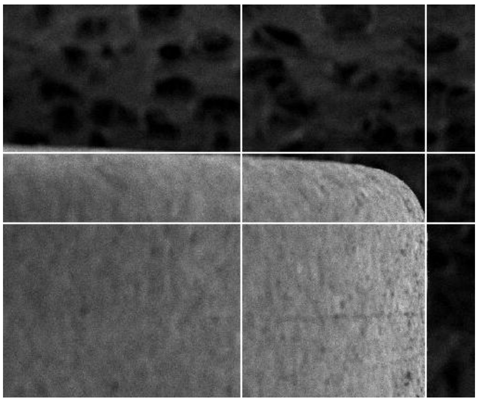

Fig. 6: Diameter 30mm; current 2.5 A

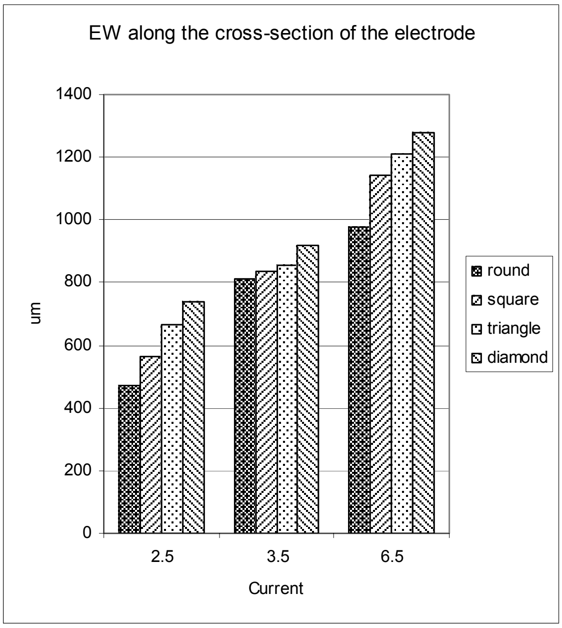

Figure 7: EW along the cross-section of electrodes with different diameters (10V)

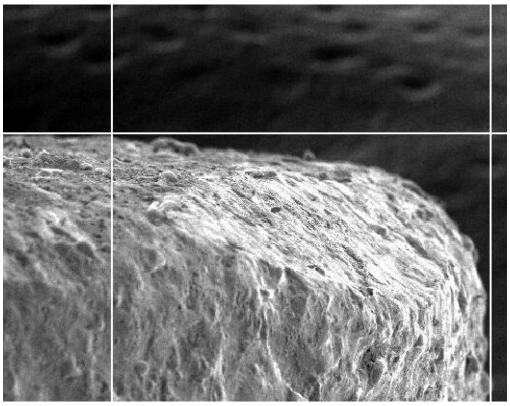

Fig. 8: Round, current 2.5 A

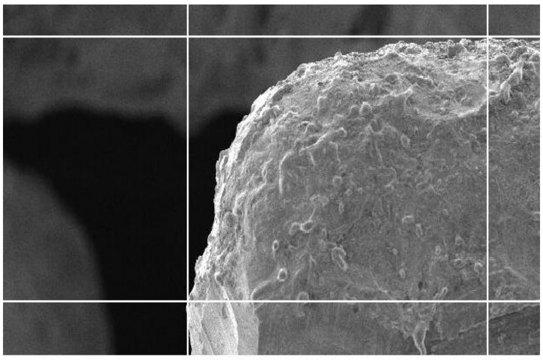

Fig. 9: Diamond shaped; current 2.5 A

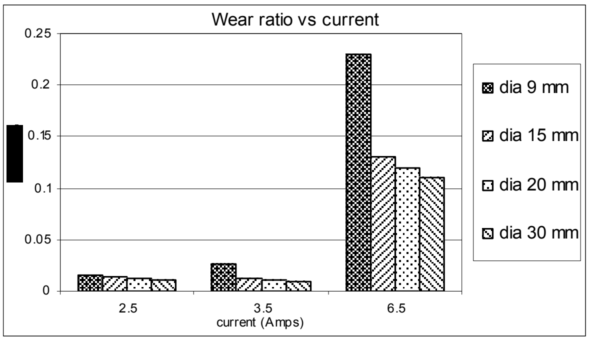

Fig.10: WR for different diameters

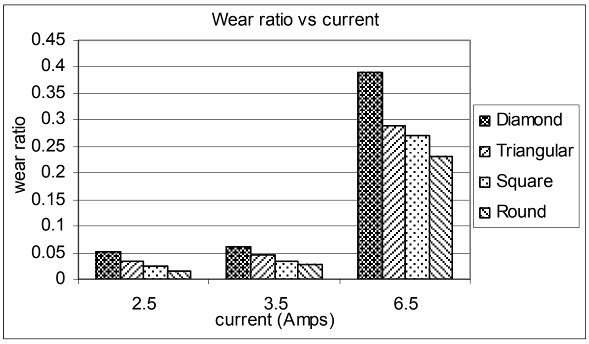

Fig.11: WR for different shapes

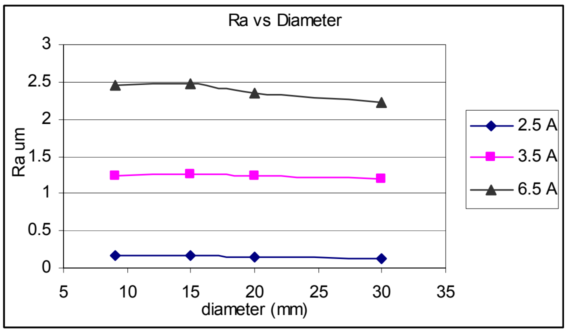

Fig. 12: Influence of electrode diameter on roughness

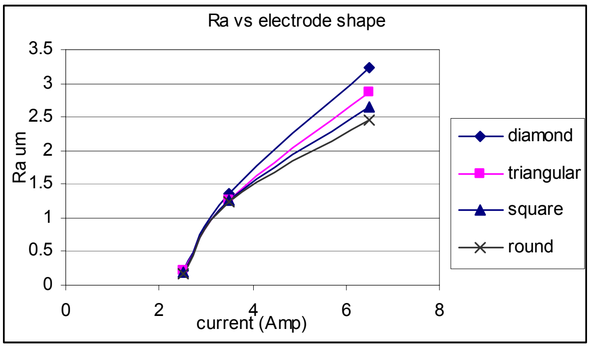

Fig. 13: Influence of electrode shape on surface roughness