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Investigation into Machining Parameters and their influence during Machining of Tool Steel using EDM

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Abstract

Copper electrodes with diameter of 9.3, 12 and 20 mm has been used in electrodischarge machining (EDM) of AISI 1043 tool steel at two current setting of 3.3 and 6.3 A with the objective of determining possible correlation between the EDM parameter (current) and the machinability factors (material removal rate and electrode wear rate). Each machining test was performed for 20 min and kerosene was used as the dielectric fluid. The material removal rate of the workpiece material and the wear rate of the electrode material were obtained based on the calculation of the percentage of mass loss per machining time (wt.%/s). It was found that the material removal rate as well as the electrode wear rate were not only dependent on the diameter of the electrode, but also had close relation with the supply of current. Low current was found suitable for small diameter electrode, while high current for big diameter electrode.

Keywords: EDM; Current; Material removal rate; Electrode wear rate

1. Introduction

From the machining technique point of view, electro- discharge machining (EDM) is classified as a non-traditional machining technique. This technique has been widely used in modern metal-working industry and its versatility and ability to cut fully hardened steels has enabled it to be widely accepted, especially in the die making industry in addition to high speed machining applications.

The basic process in EDM is carried out by producing controlled electric sparks between a tool (electrode) and the workpiece, both of which are immersed in a dielectric fluid. The electric spark raises the surface temperature of both the electrode and workpiece to a point where the surface temperatures are in excess of the melting or even boiling points of the substances [1–3]. Metal is thus primarily removed in the liquid and vapour phases. By controlling the electrical parameters, removal of material may be con- fined to some extent to the workpiece. Wear of the tool (electrode), however, cannot be ignored because when this occurs the geometrical characteristics of the electrode will not be reproduced on the workpiece. The surface generated by EDM consists of debris, which has been melted or vapourised during machining, lying on or incorporated into the cratered spark-eroded surface. This resulting product of the erosion process, commonly known as debris, has an important relation to the various aspects of EDM [4–6]. Debris formation is analog to chip formation in traditional machining, and normally debris has a spherical shape with slight elasticity. Usually, the size as well as the formation of debris depend on the current supplied during machining [3,6]. With the above in mind, studies were conducted on EDM of AISI 1043 tool steel with hardness of 230 HB using copper electrodes to determine possible correlation between the EDM parameter (current) and the machinability of the workpiece material. The machinability factors investigated were limited to the material removal rate and the electrode wear rate.

2. Experimental details

2.1. Workpiece and electrode material

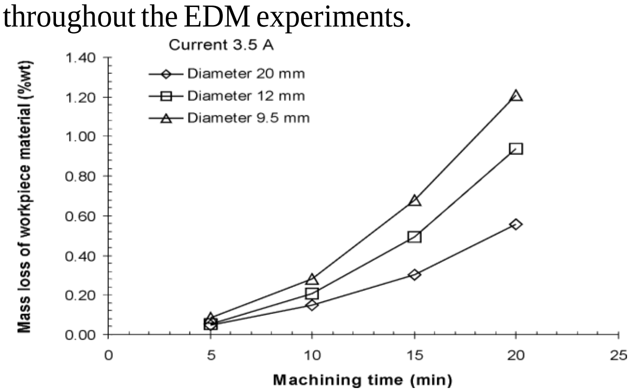
In this study, AISI 1043 tool steel was selected as the workpiece material. The material was supplied in fully annealed condition and was cut to 100 mmX100 mmX 40 mm in size. The hardness of the prepared work pieces was measured on one end of each test piece. Five points were measured and the average hardness value was found to be 230 HB. The chemical and physical properties of the workpiece material are 0.43% C and 0.70% Mn, tensile strength 640 N/mm^2 and yield point of 340 N/mm^2. Copper electrodes with diameter of 9.3, 12 and 20 mm were used in this experiment.

2.2. Experimental technique

The workpiece and the electrode were mounted on an EDM machine, Mitsubishi model M33J, and kerosene was used as the dielectric fluid. Machining tests were carried out at two current setting, i.e. 3.3 and 6.3 A, with a total machining time of 20 min for each size of electrodes. In this study, two assumptions were made: (a) temperature and pressure of dielectric fluid were assumed to be constant; (b) current consumption was constant throughout the experiments.

In order to obtain the data to show the relation between the machining parameter (current) and the machinability factors (material removal rate and electrode wear rate) when machining using EDM, a certain machining feature, namely a blind hole, was selected to be machined. A number of blind holes were machined where the diameter of the holes was the same as the diameter of the electrodes used.

Material removal rate of the workpiece material and the wear rate of the electrode were obtained based on the calculation of the percentage of mass loss per machining time (wt.%/s). The observations and measurements to deter- mine the material removal rate and the wear rate were recorded every 3 min throughout the EDM experiments.



3. Results and discussion

3.1. Material removal rate

The percentages of mass loss of workpiece material when machining at two current settings of 3.3 and 6.3 A using electrodes with diameter of 9.3, 12 and 20 mm are shown in Figs. 1 and 2, respectively. Although different in magnitude, the percentage of mass loss at higher current (6.3 A) setting is greater than at lower current (3.3 A) setting, and the trend of the curves are similar in nature.

The initial mass loss for the first 3 min of machining is almost the same for all electrodes. In Fig. 1, at current setting of 3.3 A, the initial value is 0.03–0.08 wt.%, while in Fig. 2, at current setting of 6.3 A, it is 0.33–0.73 wt.%.

From Fig. 2, it is observed that the electrode with the bigger diameter (20 mm) results in a higher percentage of Fig. 1. Percentage of mass loss of workpiece material at a current setting of 3.3 A.
Mass loss of workpiece material than the electrode with the smaller diameter (12 and 9.3 mm). In contrast, the results in Fig. 1 show that the electrode with the smaller diameter (9.3 mm) performs better than the bigger diameter (12 and 20 mm) electrodes. It seems that the electrode diameter of 20 mm is ineffective when used at a current setting of 3.3 A, but performs better when the current setting is at 6.3 A. Based on this evidence, it can be concluded that the material removal rate is not only dependent on the diameter of electrode, but also has close relation with the supply of current. Additionally, low current is found suitable for small diameter electrode whilst the high current for big diameter electrode.

Theoretically, when current is assumed to be constant throughout the EDM tests, the mass loss per machining time is supposed to be linear. However, from the curves obtained in Figs. 1 and 2, concave behaviour of curves is observed to represent the relation between the percentage of mass loss to machining time. It also found that the relation of cumulative metal removal to time was not exactly linear. This result probably occurs due to a number of reasons. First of all, there is loss of thermal energy to the atmosphere and to the dielectric fluid. Although the dielectric fluid is assumed to be at constant temperature and pressure, thermal energy is, however, absorbed by the dielectric fluid due to the high temperature generated during machining. The surface temperature in EDM is relatively high, almost equal to the melting point of the workpiece material [1–3]. Secondly, there is also the problem of debris formation and ejection. This problem is similar to that of chip ejection when milling a blind hole using a vertical milling machine under wet or dry cutting condition where chips are gathered inside the hole; in EDM, debris remains inside the hole and reduces the machining performance. Thirdly, the contact surface is reduced due to carbon deposition on the machining surface as well as on the electrode surface [2]. Moreover, the worn electrode also reduces the contact surface. Finally, there is the classical machining problem, i.e. tool vibration. In particular, when rotary EDM is employed, the electrode rotates like a tool in a milling operation and vibration may occur and this reduces the material removal rate.

Fig. 3 shows the material removal rate of the workpiece material at two current settings. It can be seen that the performance at higher current setting (6.3 A) is better than that at lower current setting (3.3 A) in terms of the material removal rate. In the case of current setting at 3.3 A, the material removal rate decreases linearly from smaller electrode diameter (9.3 mm) to higher electrode diameter (12 and 20 mm). For current setting of 6.3 A, the material removal rate increases in a convex fashion from smaller electrode diameter (9.3 mm) to higher electrode diameter (12 and 20 mm).

3.2. Electrode wear rate

The percentages of mass loss of electrodes with diameter 9.3, 12 and 20 mm when machining at two current settings of 3.3 and 6.3 A are shown in Figs. 4 and 3, respectively. From these figures, the curves can be said to have the following characteristics: (a) linear characteristic, which agrees with the theory of constant current as discussed.

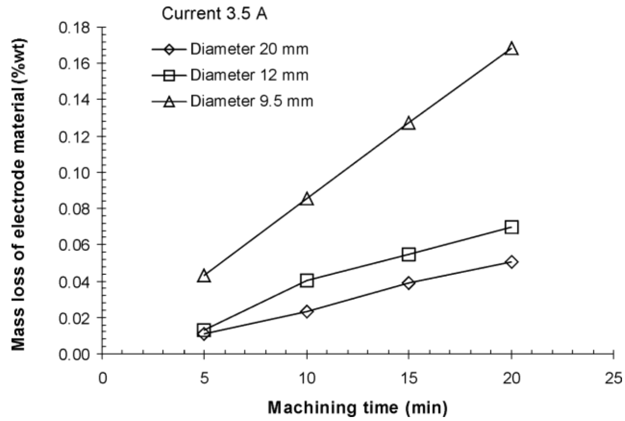


Fig. 4. Percentage of mass loss of electrode material at a current setting of 3.3 A.

previously, mostly found in Fig. 4; (b) concave curves, which are similar to the characteristics of the material removal curves, found in Fig. 3.

The initial value of electrode wear for the first 3 min is almost the same for all the electrodes and this is similar to the results of material removal rate of the workpiece as shown in Figs. 1 and 2. The exception is found only on electrode with diameter 9.3 mm at current setting of 3.3 A (Fig. 4). However, this result is the most ideal, where the curve is perfectly linear.

From the curves plotted in Fig. 4, it was observed that the electrode with smaller diameter (9.3 mm) had a higher percentage of mass loss than the electrode with bigger diameter, such as 12 and 20 mm. It is expected that this characteristic also applies to the results in Fig. 3 when 6.3 A of current is supplied. This expectation is supported by the fact that the initial value of wear or mass loss of the electrode with 9.3 mm diameter is higher than the initial wear value of electrode with 12 mm diameter (Fig. 3). However, the curves in Fig. 3 show that the mass loss of the electrode with 12 mm diameter is higher than the electrode with 9.3 mm diameter, while the electrode with 20 mm diameter still satisfies the expectation. The occurrence of the unexpected result may be due to two main reasons, i.e. thermal loss during machining

and the melting point of electrode material. When the electrode with 12 mm diameter was used, thermal energy lost to the atmosphere and the dielectric liquid was more than that using electrode with 9.3 mm diameter. Thus, the temperature was not constant when approaching the melting point of electrode material. As a result, wear or mass loss on the electrode with 12 mm diameter is less than the wear or mass loss on the electrode with 9.3 mm diameter.

Further description of the wear rate of electrode at the two current settings is presented in Fig. 6. In the case of current setting at 3.3 A, the wear rate decreases in a concave manner from the smaller electrode diameter (9.3 mm) to the higher electrode diameter (12 and 20 mm). For a current setting of 6.3 A, higher wear rate is on the electrode diameter of 12 mm, followed by 9.3 and 20 mm.

From the discussion of the material removal rate and wear rate, it can be concluded that the best performance is given by the electrode diameter of 20 mm with a current setting of 6.3 A, since this combination gives the highest material removal rate.

4. Conclusions

The following conclusions are drawn to describe the relation of the machining parameter (current) and the machinability factors (material removal rate and electrode wear rate) when machining tool steel using EDM.

1. Based on the material removal rate of the workpiece and wear rate of the electrode, it can be concluded that the best performance was given by electrode with a diameter of 20 mm at a current setting of 6.3 A, since this combination gives the highest material removal rate and the lowest wear rate.
2. The curves representing the percentages of mass loss of workpiece material when machining at two current setting of 3.3 and 6.3A using copper electrodes with diameter of 9.3, 12 and 20 mm are different in magnitude, but similar in trend.
3. The initial value of mass loss, both for the workpiece material (material removal) and electrode material (wear), for the first 3 min of machining was almost the same for all electrodes used in this study.
4. The material removal rate and the electrode wear rate were not only dependent on the diameter of electrode, but also had close relation with the supply of current. Low current was found suitable for small diameter electrode, and high current for big diameter electrode.
5. Concave behaviour of curves was observed to represent the relation between the percentage of mass loss of workpiece material and the machining time. This result probably occurs due to the following reasons: (a) thermal energy lost to the atmosphere and to the dielectric fluid; (b) the problem of debris formation and ejection; (c) carbon deposition and wear reduce the contact surface; (d) vibration of electrode.
6. In the case of current setting at 3.3 A, the material removal rate decreases linearly from the smaller electrode diameter (9.3 mm) to the higher electrode diameter (12 and 20 mm). For current setting of 6.3 A, the material removal rate increases in a convex manner from the smaller electrode diameter (9.3 mm) to the higher electrode diameter (12 and 20 mm).
7. In case the current is 3.3 A, the wear rate decreases in a concave manner from the smaller electrode diameter (9.3 mm) to the higher electrode diameter (12 and 20 mm). For current setting of 6.3A, higher wear rate was observed on the electrode diameter of 12 mm, followed by 9.3 and 20 mm.

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