Investigation on Applicability of Diatomite Powder-Mixed Dielectric Fluid in Electrical Discharge Machining Processes

J. M. Muniu, B.W. Ikua, D.M. Nyaanga and S.N. Gicharu

***Abstract*—**Powder-mixed electrical discharge machining is one of the latest techniques for improving material removal rate and electrode wear ratio among other performance characteristics. However, its utilization in the manufacturing industry is very low because many fundamental issues of this new development such as machining mechanism, cost effectiveness of powders and powder concentration in the working fluid together with safety and environmental impact among others, are not well understood.

The objective of this study was to investigate diatomite as a potential powder for suspension in dielectric fluids of electrical discharge machines. The effect of diatomite powder suspended in distilled water is investigated using a graphite tool electrode on mild steel workpiece. The process parameters used are peak current, pulse-on time and powder concentration.

Completely randomized design is used to plan and analyze the experiments which are performed on toolcraft A25 sinker electrical discharge machine with retrofitted dielectric fluid circulation system. Analysis of variance is performed at 5% level of significance.

The experimental results show that the suspension of diatomite powder in dielectric fluid improves the performance characteristics of conventional electrical discharge machining process and future research based on these findings have been outlined.

Keywords: Diatomite powder, Electrical Discharge Machining, Electrode Wear Ratio, Machine Performance Characteristics, Material Removal Rate, Powder-Mixed Electrical Discharge Machining and Tool Wear Rate.

I. Introduction

Electrical Discharge Machining (EDM) is a non-traditional material removal method which has been widely used in the die and mould, machine tools and aerospace industries [1]. EDM is a well-established machining option for manufacturing geometrically complex parts or hard materials that are extremely difficult to machine by the conventional machining processes such as milling. The EDM process uses thermal energy to erode the tool and the workpiece immersed in a dielectric fluid through a series of current discharges subject to an electric voltage. When a voltage of 35 – 320 V is applied between the tool electrode and the workpiece placed close to each other, an electric field in the range of 10^5- 10^7 V/m is generated [2]. This potential difference is the one that enables sparking and hence, material removal. Since there is no direct contact between workpiece and tool electrode in EDM, problems usually associated with machining such as mechanical stresses and vibrations do not arise during machining process [2]. However, in spite of its remarkable process capabilities, EDM process suffers from low volumetric removal rate, high tool wear rate and poor surface finish which restrict its applications [3]. To address these limitations, Powder-Mixed EDM (PMEDM) has emerged as one of the latest advanced techniques of enhancing the EDM capabilities [4].

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PMEDM has a different machining mechanism from the conventional EDM [5]. In this process, a suitable material in the powder form of e.g., Nickel, Cobalt, Iron, Aluminium, Copper, Carbon or Silicon carbide [7, 17] is mixed into the dielectric fluid in the same tank or in a separate tank. The powder particles filling the spark gap get energized and are accelerated by the electric field and act like conductors forming chains which bridge the gap between the tool electrode and the workpiece leading to an early explosion. As a result, the gap voltage and the insulating strength of the dielectric fluid reduce which enhances the ignition process causing faster erosion from the work piece surface [8]. The discharge behaves in a zigzag fashion and spread uniformly in all directions, resulting to an enlarged and widened discharge channel with uniform distribution of sparking on the workpiece leading to decreased electric density and improved surface finish [9].

There has been a lot of research interest on this subject. In their study, Erden and Bilgin [5] reported that machining rate of mild steel workpiece increases with addition of carbon, iron, aluminium and copper powder particles in the dielectric fluid of EDM during machining.

Kung *et al.* [6] analyzed Material Removal Rate MRR and Electrode Wear Ratio (EWR) in Powder-Mixed Electrical Discharge Machining (PMEDM) of cobalt-bonded tungsten carbide by suspending aluminium powder in dielectric fluid and reported that the powder particles disperses making the discharge energy dispersion uniform.

According to Zhao *et al.* [9], the addition of powder into dielectric fluids of EDM helps to produce smaller and shallower craters on the surface of workpiece. Kansal *et al.* [11] optimized the process parameters of PMEDM and concluded that silicon powder suspended in the dielectric fluid of the EDM increases MRR and was set to improve with increased powder concentration. But on the contrary, Kozak *et al.* [12] studied electrical discharge machining using powder suspended in working media and reported that MRR decreased as powder concentration increased. Increase in powder concentration results to higher TWR but after certain level it starts to reduce [4]. Singh *et al.* [3] experimented on the influence of electrical parameters in powder mixed electric discharge machining of hastelloy and reported that TWR decreases as peak current increases.

Ojha *et al.*, [4] added that increasing the peak current results into a considerable increase in MRR. Material removal in conventional EDM is usually very low [13]. However, with the addition of aluminium powder in the dielectric fluid, material removal rate increased sharply.

Tzeng and Lee [14] studied the effects of powder characteristics on electrical discharge machining efficiency and concluded that particle size, concentration, density, electrical resistivity and thermal conductivity are the most important characteristics that affect the EDM performance. Sharma *et al.* [13] researched on the effects of aluminium powder addition during electric discharge machining of hastelloy on machining performance using reverse polarity and concluded that increase in powder concentration results in sharp decrease in wear rate.

While investigating roughness of EDMed surface using powder mixed dielectric, Celik [15] reported that material removal rate depends not only on the workpiece material and electrode qualities, but the parameters applied in EDM and the characteristics of dielectric fluid.

Material removal rate increased with addition of aluminium powder in the dielectric fluid of EDM and the increase in its grain size caused continuous increase in the material removal rate [13].

Form the above literature, it is clear that PMEDM has been found to improve the machining performance of the EDM process [8]. However, application of PMEDM in the manufacturing industry is still very low. This could be because many fundamental issues of this new development such as the amount of powder consumption, machining mechanism, cost effectiveness of the powders in the working fluid together with environmental impacts are not well understood.

The objective of this study was to investigate the effects of diatomite powder suspension in distilled water on material removal rate, tool wear rate and electrode wear ratio and compare its performance with that of conventional EDM process. Diatomite and distilled water are chosen since these are readily available, cheap, safe to use and environmentally friendly.

II. EXPERIMENTAL SETUP

This research was conducted at Diemould Machinery Product and Services (DMPS) premises at Kahawa Sukari in Nairobi using a sinker EDM (Toolcraft A25) shown in Fig. 1.

A dielectric fluid system was retrofitted to allow easy accessibility, cleaning, suspension and circulation of diatomite powder-mixed distilled water besides filtering the debris using permanent magnets placed within the tanks (Figs. 2 and 5). This system consisted of a stirring motor and a centrifugal pump, which were mounted on a stand housing the mixing tank. The mixing tank was linked to the machining tank through transparent pipes with nozzles at the ends. See Fig. 4.

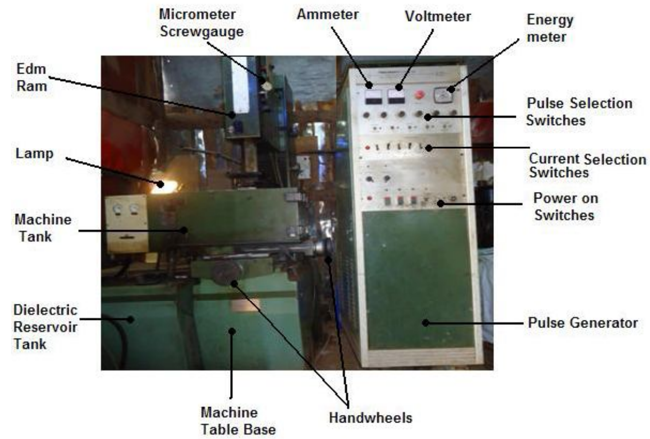

Fig. 1 Sinker EDM (A25) machine

Figs. 2 and 3 show the line and block diagrams of the experimental arrangement of the improvised dielectric fluid circulation system, respectively.

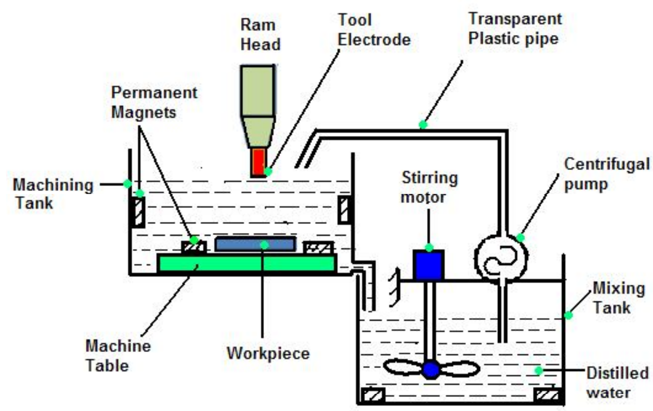

Fig. 2: Line diagram of the Powder Mixed EDM experimental set-up.

Machining was done initially with pure distilled water (i.e., without powder) for 10 minutes. The material removed was determined by taking the difference in weights before and after the machining process. A digital balance was used in weight measurements.

Except for the input process parameters, which were assigned four levels, the rest of the variables were treated as design factors as given in Table 1. Pilot experiments were conducted as suggested by Jangra *et al.* [12] and the selection of the range and values of process parameters was based on suggestions made by Ojha *et al.* [4], the machine specifications and personal experience gained through trial runs.

The duty cycle of 0.5 was adopted as standard in the for experiments on peak currents since it would give optimum MRR [6], while powder concentration experiments were done at the same duty cycle and peak current of 21A which ensured maximum MRR. Since MRR, TWR and EWR machining characteristics depict the efficiency of the machining process [18], they are essential parameters in EDM.

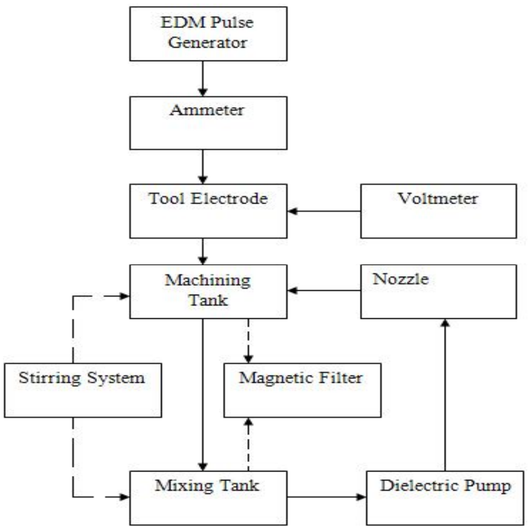

Fig. 3: Block diagram of the powder mixed EDM system.

The material for the electrodes used was graphite. Initially, the workpieces were surface-ground so that when fixed at the bottom of the machine tank, it would be easier to set the tool flat and perpendicular to the workpiece. The choice of direct polarity was based on the finding of Khan and Hameedullah [19] since it gives between 4 and11 times higher MRR and 5 times less relative electrode wear as compared to reverse polarity.

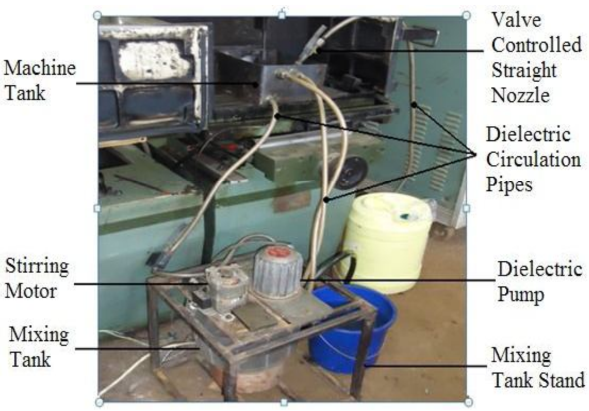

Fig. 4: Improvised dielectric fluid circulation system.

A. Dielectric fluid circulation system

A machining tank of 260 mm x 198 mm x 130 mm was fabricated for the experiments. This tank was placed inside the main machine tank (Fig. 4) at a height that ensured dielectric fluid flowed back to the mixing tank by gravity. A zigzag flushing method was incorporated as per the recommendations of Singh *et al.* [3] to prevent the particles from settling at the bottom of the tanks and ensuring uniform distribution of powder particles in the dielectric circulation system.

The dielectric pump was used to maintain a constant flow of the dielectric between the mixing and machining tanks. The dielectric fluid was discharged into the machining tank in a zigzag fashion through a nozzle to ensure the mixer remained homogeneous during the machining process and facilitate effective material removal.

Table 1: Process parameters used for in experiments

Process variable	Value
Supply voltage (*V*)	70 V
Current (*I*)	3 - 21 A
Pulse duration (T_{on})	45 -135μs
Pulse off time (T_{off})	50 and 70μS
Powder concentration	2 - 8 g/l
Type of flushing	Straight nozzle flushing
Polarity of electrode	- ve (Direct polarity)
Duty cycle	0.5
Electrode lift time	0.2 s
Diameter of tool electrode	25 mm
Tool material	Graphite
Workpiece material	Mild steel
Powder type	Diatomite
Dielectric fluid	Distilled water

In order to separate the debris from the dielectric fluid immediately after the machining process, permanent magnets were strategically placed inside the mixing and machining tanks (Figs. 2 and 6) to remove impurities. Permanent magnets were placed in close proximity on a fixture and on the sides of the machining tank to establish a strong magnetic field which would promptly attract the iron debris eroded from the workpiece separating them from the circulating dielectric fluid.

Fig. 5 shows perforations machined on mild steel by circular graphite electrode and iron debris attracted and aligned along the magnetic lines of forces during the machining process.

Fig. 6: Debris separation mechanism from dielectric fluid using magnetic forces.

Fig. 7 shows the experimental setup, including data collection equipments and the improvised dielectric circulation system integrated with the pulse generator. A stop watch with accuracy of 0.01 s and an electronic balance (AF 300/0.01) with an accuracy of 0.01 g were employed to determine time and weight measurements.

B. Determination of influence of diatomite powder and concentration on machining characteristics

Diatomite powder was added into distilled water at concentrations of 2, 4, 6 and 8 g/l and machining performed at a peak current of 21A, pulse frequency of 10 KHz and duty cycle of 0.5. Then, material removal rate, tool wear rate and electrode wear ratio values were computed from the data.

C. Determination of influence of process parameters on Machining Performance

The performance characteristics subject to investigation with variation in peak current and pulse-on time were material removal rate, tool wear rate and electrode wear ratio.

For peak current experiments, duty cycle was fixed at 0.5 and pulse frequency at 10 KHz.

The weights of the tool and workpiece were measured prior to machining and then fixed onto the ram head and bottom of the machine tank, respectively. Experiments were performed at peak currents of 3, 9, 15 and 21A for 10 minutes each using pure dielectric (distilled water) with two replications. Diatomite powder was then suspended in distilled water at 2 grams per liter and the powder-mixed dielectric was pumped into the machine tank until both the electrode and the workpiece were completely submerged. Again, peak current was varied from 3A through 21A for the same period and replications and results computed for MRR and TWR, while EWR was derived from the ratio of TWR to MRR. The amount of energy produced by a single spark is given by (1).

$$E_i = V_g I_P t_{on} \tag{1}$$

Where; E_i is energy in joules,
V_g is voltage of a single pulse,
I_p is current of a single pulse,
t_{on} is pulse-on time,

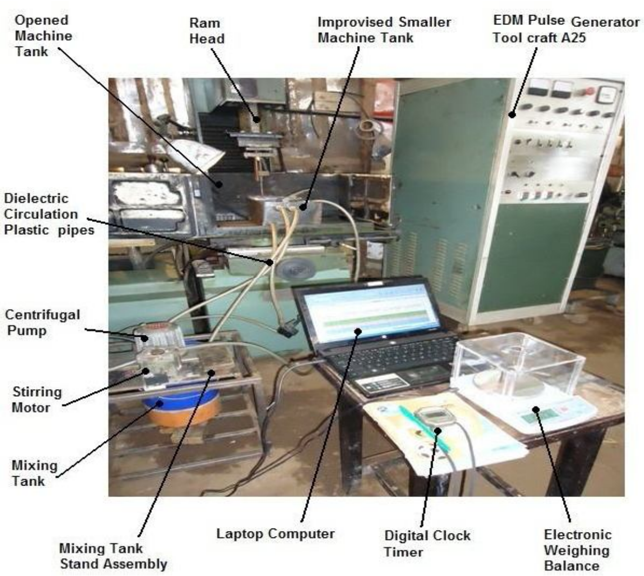

Fig. 5: Instrumentation of the EDM experiments.

Experiments on pulse-on time were carried out at peak current of 21A and powder concentration of 2 g/l. Pulse-on time was varied from 45 to 135 μs and weight differences per minute for the tool and workpiece for distilled water with and without diatomite powder suspension were determined.

III. RESEARCH DESIGN

Completely Randomized Design (CRD) was adopted for this study to test the effects of peak current, concentration and pulse-on time on the EDM machining performance in terms of MRR, TWR and EWR which were subjected to analysis of variance using Statistical Analysis of Systems (SAS) at 5% level of significance.

IV. RESULTS AND DISCUSSION

A. Effects of diatomite powder on material removal rate

The mean MRR for diatomite was 0.2525 g/min and that of pure dielectric was 0.2005 g/min at 21A and duty cycle of 0.5 and pulse frequency of 10 KHz.

As is seen from Fig. 8, the response of MRR shows a positive trend with increase in concentration up to a maximum of 0.2655 g/min at 6 g/l before starting to decrease with further increase in powder concentration. This increase of MRR with concentration could be attributed to the fact that with addition of diatomite powder particles in distilled water, spark gap is filled with additive particles which reduces the insulating strength of the dielectric fluid and increased spark gap between the graphite electrode and the workpiece. It was also possible that the best combination of particle striking and powder density takes place at this concentration.

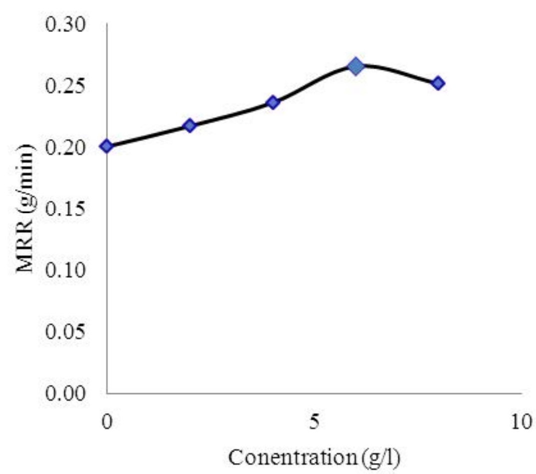

Fig. 8: Material removal rate with increase in diatomite powder concentration.

The decrease of MRR after 6 g/l could be attributed to short circuiting at higher powder density which causes the machining process to become unstable leading to net reduction in MRR.

B. Effects of diatomite powder concentration on tool wear rate

As seen in Fig. 9, TWR due to diatomite suspension increased sharply from 0.0160g/min to around 0.0311g/min as concentration was increased from 2g/l to 6 g/l. On further increase in concentration, there is no significant change in TWR.

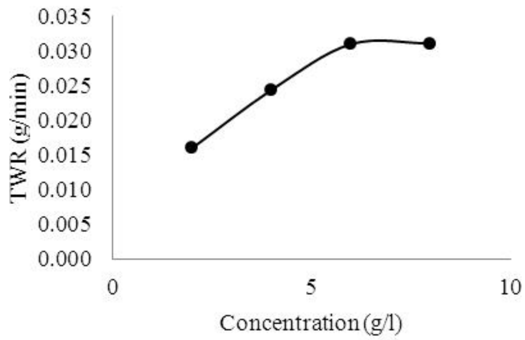

Fig. 6: TWR due to variations in concentration.

These findings agree with the observations made by Ojha *et al.* [18] which gave an approximate value of TWR (0.025 g/min) at 4 g/l using kerosene dielectric.

C. *Effects of diatomite powder on electrode wear ratio*

Table 2 presents average EWR for pure and diatomite powder-mixed dielectrics. From results, it is clear that the mean EWR reduced by 23% when diatomite powder was added to distilled water.

Variation of diatomite powder concentration from 2 g/l to 8 g/l produced EWR values ranging between 0.0736 and 0.1237 (Fig. 10) while the mean EWR for pure dielectric was 0.1355. The response of EWR had a positive trend due to the fact that TWR increased with concentration at a faster rate (between 2 g/l to 6 g/l) than MRR as can be seen in Figs. 7 and 8.

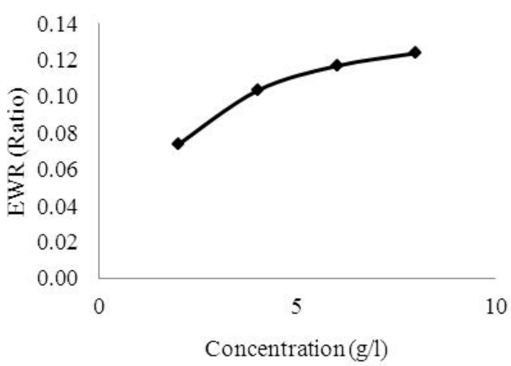

Fig. 7: Electrode wear ratio with variation in concentration.

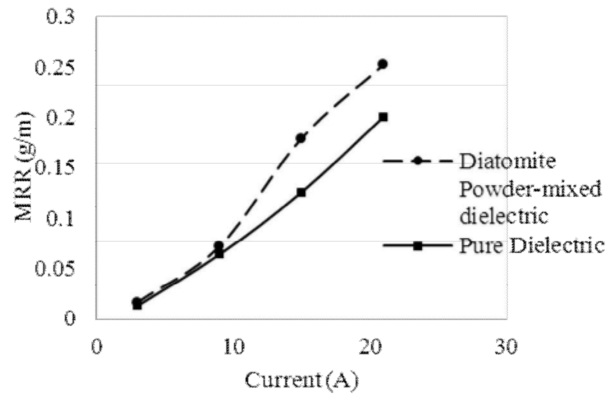

Fig. 8: Effects of varying current on material removal rate.

D. *Effect of peak current on MRR*

At low values of current (3A- 9A), MRR is small because the amount of heat produced is little and a substantial portion of it is absorbed by the machine components and the surroundings as shown in Fig. 11. As a result, the remnant energy utilized in melting and vaporizing the electrodes is not so intense. But, as current is increased further (9A to 21A), a stronger spark with higher thermal energy is produced which results to more intense discharge strikes on the surfaces of the electrodes causing more molten material to be removed. These results agree with the findings of Shabgard *et al.* [20] who reported that MRR increased from 10 mm^3/min to 55 mm^3/min as current was varied from 8 amperes to 24 amperes at pulse-on time of 100 µS. Ojha *et al.* [18] further reported that material removal rate ranged from 4 mm^3/min to 35 mm^3/min when current was increased from 3 amperes to 12 amperes, respectively.

The MRR means due to variation of peak current are given in Table 1. The means of diatomite powder-mixed and pure dielectrics are 0.1301 g/min and 0.1008 g/min, respectively.

As is seen from Fig. 10, MRR for pure dielectric increased from 0.0089 g/min to 0.2316 g/min when current was increased from 3A to 21A, respectively. However, at peak currents higher than 9A, addition of diatomite powder into distilled water improved MRR by 29%.

E. *Influence of peak current on tool wear rate*

As can be seen in this Figure 12, use of diatomite resulted to higher TWR than with pure dielectric for currents above 6A and means ranged between 0.0032 g/min and 0.0280 g/min with increase in peak current. This increase in TWR could be attributed to variation in temperature, increased gas volume and contamination in the machining gap as was suggested by Ozgedik and Cogun [22].

Table 2: Averages of machine performance characteristics with variations in process parameters.

Process parameters	MRR (g/min) Pure dielectric	MRR (g/min) Diatomite powder-mixed dielectric	TWR(g/min) Pure dielectric	TWR(g/min) Diatomite powder-mixed dielectric	EWR (Ratio) Pure dielectric	EWR (Ratio) Diatomite powder-mixed dielectric
Concentration (g/l)	0.2005	0.2525	0.0230	0.0280	0.1355	0.1110
Peak current (A)	0.1008	0.1301	0.0155	0.0164	0.2895	0.1556
Pulse-on time (µS)	0.0393	0.0520	0.0075	0.0070	0.3445	0.1746

As current was varied from 3A to 21A, the mean difference in TWR ranged from -66% to 22% which averaged to 6%. The increase in TWR could be attributed to electrons hitting the tool electrode surface with increased discharge energy.

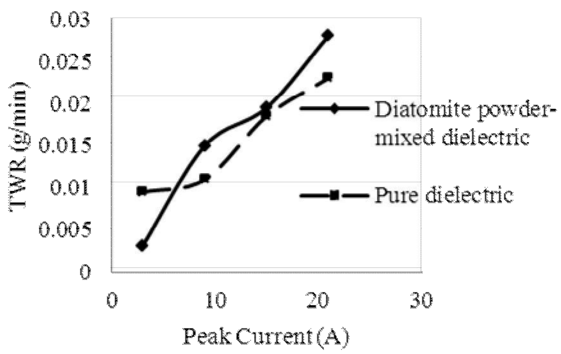

Fig. 12: Effects of varying current on tool wear rate.

F. Influence of peak current on electrode wear ratio

Electrode wear ratio is the ratio of tool wear rate to material removal rate. Fig. 13 shows responses for EWR due to variation in peak current for pure and diatomite powder-mixed dielectrics while their means are presented in Table 2. At 3A, EWR for pure dielectric was higher than that of diatomite powder-mixed dielectric by 274%, but decreased sharply to tie with diatomite powder-mixed dielectric (0.2083) at 8A and stabilized around 0.1292 with further increase in peak current. Increasing peak current from 3A to 9A in pure dielectric resulted to reduction in EWR while EWR for powder-mixed dielectric remained fairly low within this range.

Increasing peak current from 3A to 21A realized a change in EWR for powder-mixed and pure dielectric fluids ranging from 0.1945 to 0.1110 and 0.7277 to 0.1355, respectively. High values of EWR at low peak current could be attributed to the fact that at low current, low discharge energy is generated (1) and much of it is spent in heating the dielectric, the environment and machine components.

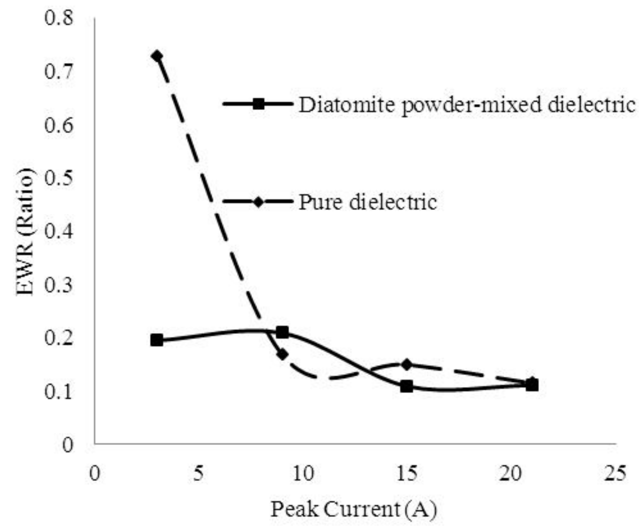

Fig. 13: Effects of peak current on electrode wear ratio.

G. Influence of pulse-on time on material removal rate

Pulse-on time is an important input parameter that has significant effects on material removal rate. Higher pulse-on time leads to spark energy being induced for a longer time which results to larger craters on workpiece indicating high MRR. Table 2 shows the means of MRR for diatomite powder-mixed and pure dielectrics while Fig. 14 presents MRR with variations in pulse-on time at constant peak current of 21A. The result shows that variation of pulse-on time in diatomite powder-mixed dielectric improved the mean MRR by 32%. Material removal rate in EDM is an important factor due to its vital effects on the industrial economy. MRR due to pure dielectric ranged from 0.0060 g/min to 0.0670 g/min as pulse-on time was increased from 45 µS to 135 µS with maximum value occurring at 105 µS after which it dropped to minimum. On the other hand, variation of pulse-on time in diatomite powder-mixed dielectric improved MRR with between 17% and 57%. MRR was found to initially increase to maximum value with pulse-on time up to 90 µS and 100 µS for pure and diatomite powder-mixed dielectrics, respectively but started to decrease sharply with further increase in pulse-on time.

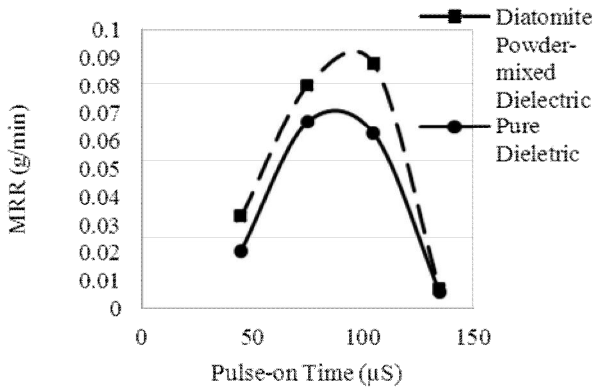

Fig. 14: Material removal rate with variation in pulse-on time.

The response for MRR diatomite powder-mixed dielectric is skewed towards 105 μS and further scrutiny of the results suggests that machining in diatomite powder-mixed dielectric increased MRR. The decrease in MRR after maxima in both dielectrics could be attributed to high gap pollution and low energy density during pulse-on time as was suggested by Shabgard and Shotorbani [23], Tzeng and Lee [14] and Singh *et al.* [3]. This decrease in MRR could also be attributed to inefficient dielectric flushing method of debris from between the faces of the electrodes plus ageing of and the operational bandwidth of Tool Craft A25 EDM machine used to conduct the experiments.

H. Influence of pulse-on time on tool wear rate

For effective and efficient electrical discharge machining process to take place, low tool wear rate is desirable during the machining process. As shown in Fig. 15, TWR for pure dielectric increased at a lower rate than TWR for diatomite powder-mixed dielectric with maximum values occurring at 105 μS and 75 μS, respectively and both decreased with further increase in pulse duration.

The shift in pulse-on response after suspension of diatomite powder into distilled water is a good indicator that operating the equipment at 105 μS would greatly minimize tool wear by about 40%.

When pulse-on time is increased, the discharge energy into the electrodes increases together with the dimensions of plasma channel and the effects of thermal conductivity of electrodes in dispersing the thermal energy from the collision position. Consequently, more heat energy (1) is dispersed from the spark stricken position and increases the amount of heat transferred from the plasma channel to the electrodes causing the plasma channel efficiency (removing molten material from the molten crater at the end of each pulse) to decrease while the dimensions of molten crater on the electrodes increases.

The means of TWR due to variation in pulse-on time are presented in Table 2. The means for diatomite powder-mixed and pure dielectrics were 0.0070 and 0.0075, respectively. It was observed from Fig. 17 that variation in pulse-on time resulted to TWR ranging between 0.0030 g/min to 0.0120 g/min and 0.0020 g/min to 0.0150 g/min for pure and powder-mixed dielectrics, respectively. Compared to pure dielectric, suspension of diatomite into distilled water resulted to a decrease in mean TWR by 7%.

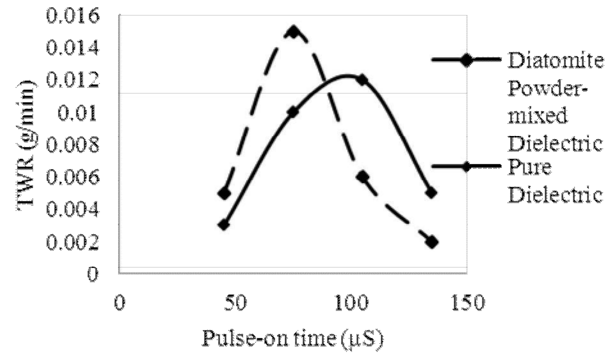

Fig. 15: Effects of variations of pulse-on time on TWR.

For both dielectrics, TWR initially increased with pulse-on time reaching maximum at some point, before starting to decrease with further increase pulse-on time. This decrease in TWR could be attributed to decreasing spatial current density of the discharge channel with increasing discharge duration and longer time for heat transfer from the molten crater to the body of the tool which results in lower tool wear.

This phenomenon agrees with the findings of Shabgard *et al.* [20] which were similar to the findings of Cogun and Akaslan [20] on the effects of machining parameters on tool wear and machining performance in electric discharge machining. These results were also in line with the findings of Lee and Li [23] on the study of the effects of machining parameters on the machining characteristics in electrical discharge machining of tungsten carbide.

I. Influence of pulse-on time on electrode wear ratio

Electrode Wear Ratio (EWR) signifies effectiveness of the electrical discharge machining process and is given by the ratio of tool wear rate to material removal rate. Fig. 16 shows EWR means due to variations in pulse-on time. Suspending diatomite powder into distilled water reduced the EWR mean from 0.3445 to 0.1746 which was a net reduction of 49%. As pulse-on time was increased from 45 to 135 μs, changes in EWR ranged from 0.1493 to 0.8750 and 0.0683 to 0.2917 for pure dielectric and diatomite powder-mixed dielectric, respectively. The EWR means between 45 and 105 μs were lower compared those experienced at higher pulse-on time with maxima occurring at 135 μs. The EWR for diatomite powder-mixed dielectric decreased slightly between 45 μs and 105 μs while that for pure dielectric remained fairly constant before rising sharply towards maxima with further increase in pulse-on time. This implies that it would be inefficient and uneconomical to machine mild steel with graphite at 135 μs.

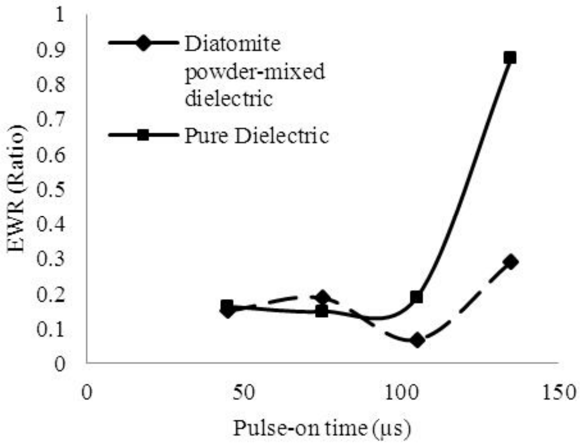

Fig. 16: EWR due to variations in pulse-on time.

EWR rises sharply between 105 μs and 135 μs which could be attributed to MRR decreasing at a faster rate at higher pulse-on time due to expansion of the plasma channel as compared to TWR. These results compare with the findings of Singh *et al.* [2] on aluminium Powder Mixed EDM when machining hastelloy steel.

V. CONCLUSIONS

In this paper, the suitability of the use of diatomite powder in EDM process was investigated. The study showed that the suspension of diatomite powder into distilled water improves the performance of electro-discharge machining process. Other observations are as follows:

- ✓ Addition of diatomite powder into distilled water reduces both tool wear rate and electrode wear ratio at the pulse-on time which produces maximum material removal rate.
- ✓ Material removal rate increases with increase in diatomite powder concentration up to a maximum value before starting to decrease with further increase in concentration.
- ✓ Electro-discharge machining in diatomite powder-mixed dielectric fluids results to higher MRR with variation in pulse-on time. MRR initially increases with pulse-on time, but decreases at some point with further increase in pulse-on time.
- ✓ Tool wear rate increases with both concentration and current, while it increases to a maximum before decreasing with further increase in pulse-on time.
- ✓ Diatomite powder-mixed distilled water produces lower tool wear rate and electrode wear ratio compared to that of pure dielectric.
- ✓ Though, EWR remains relatively constant at low pulse-on time and higher peak currents, addition of diatomite powder into distilled water causes to a substantial reduction in EWR which increases with increasing concentration and higher pulse-on time.
- ✓ Increasing peak current in diatomite powder-mixed distilled water results to reduced electrode wear ratio and increase in both material removal rate and tool wear rate.
- ✓ Diatomite powder-mixed distilled water can be used in place of silicon carbide, aluminium, copper and other powder-suspended dielectrics in some applications because it is less expensive.

VI. RECOMMENDATIONS

To fully understand the parameters affecting the performance characteristics of the EDM process it is recommended that the following investigations be carried out:

- Explore the influence of temperature of the dielectric fluid on electro-discharge machining process.
- Investigate the effects of diatomite powder concentration on surface characteristics of the workpiece.
- Investigate the influence of aluminium, copper and diatomite powders on recast layer.
- Investigate the effects of machining in diatomite powder-mixed dielectric fluid using electrodes other than graphite.
- Investigate the influence of electrical parameters and diatomite powder suspension in kerosene on electrical discharge machining process.
- Model and optimize process parameters in diatomite powder-mixed EDM.

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