Experimental Investigations in Powder Mixed Electric Discharge Machining of Al6063 Aluminum Alloy

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Abstract

In the present research work, Al6063 aluminum alloy has been machined by powder mixed Electric discharge machining (PMEDM) process. The effect of various process parameters namely pulse on time, pulse off time and silicon powder concentration on the performance measures such as material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) has been investigated. The experiments were carried out as per design of experiments approach using L9 orthogonal array. It has been analyzed that the peak current and powder concentration have significant effect on MRR, TWR and SR. Moreover, it has also been concluded that the addition of silicon powder into the dielectric fluid of EDM resulted in an increase in MRR whereas TWR, SR has been decreased. The results from this study will be useful for manufacturing engineers to select appropriate PMEDM process parameters to machine Al6063 aluminum alloys.

Key Words: Powder Mixed EDM, Material removal rate, Tool wear rate, Surface roughness, Al6063 Aluminum alloy

1. INTRODUCTION

Electrical discharge machining (EDM) is a unconventional machining successfully employed for machining of complex shapes, intricate profiles, hard materials that are extremely difficult to machine by conventional machining processes. It can be successfully employed to machine electrically conductive parts regardless of their hardness and strength. In spite of remarkable process capabilities, limitations such as less material removal rate and poor surface quality are associated with EDM. In the recent past, powder mixed EDM (PMEDM) has emerged as one of the advanced techniques in the direction of the enhancement of the process capabilities of EDM [1]. In this process, a suitable material in fine powder form is mixed into the dielectric fluid of EDM. The spark gap is filled up with additive particles. The added powder significantly affects the performance of EDM process. The electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap distance between the tool electrode and workpiece. As a result, the process becomes more stable, thereby improving surface finish [2].

2. TECHNOLOGY AND PROCESS MECHANISM OF PMEDM

PMEDM is differentiated from conventional EDM due to its entirely different principle of operation [3]. In this process, fine abrasive powder particles were mixed in to the dielectric fluid of EDM in a separate tank. Stirring system is generally employed in this tank to achieve homogeneous dispersion and circulation of powder in to dielectric fluid. The tool and workpiece are supplied with a suitable voltage ranging from 80–320 V leading to the generation of an electric field of 105–107 V/m. Spark gap is filled with additive particles supplied through flushing, thereby causing an increase in the gap distance between workpiece and tool from 25–50 µm to 50–150 µm [4]. A large amount of energy is accumulated in the powder particles due to the influence of electric field resulting in charging up of particles .These accelerated particles move in zig-zag way and act as conductors promoting breakdown in the gap and widens the spark gap between the electrodes. The particles accumulate under the sparking area and move either in reciprocating motion, adhered to either electrode, gather in clusters or form a chain like structure connecting the electrodes. An irregularity in shape and size of powder particles result in interlocking and may lead to chain formation. The bridging effect reduces the insulating strength of the dielectric fluid leading to easy short circuiting and hence an early explosion in the gap. A ‘series discharge’ occurs under the electrode area due to early explosion. The workpiece erodes at a higher rate due to quick sparking under the electrode area. The striking effect of the particles and discharge transitivity increases MRR. At the same moment, the added powder enlarged and widened the plasma channel. Even distribution of sparking among the powder particles leads to reduction in electric density of the spark. Therefore, flat craters are formed on the workpiece surface. Hence the surface finish is improved.

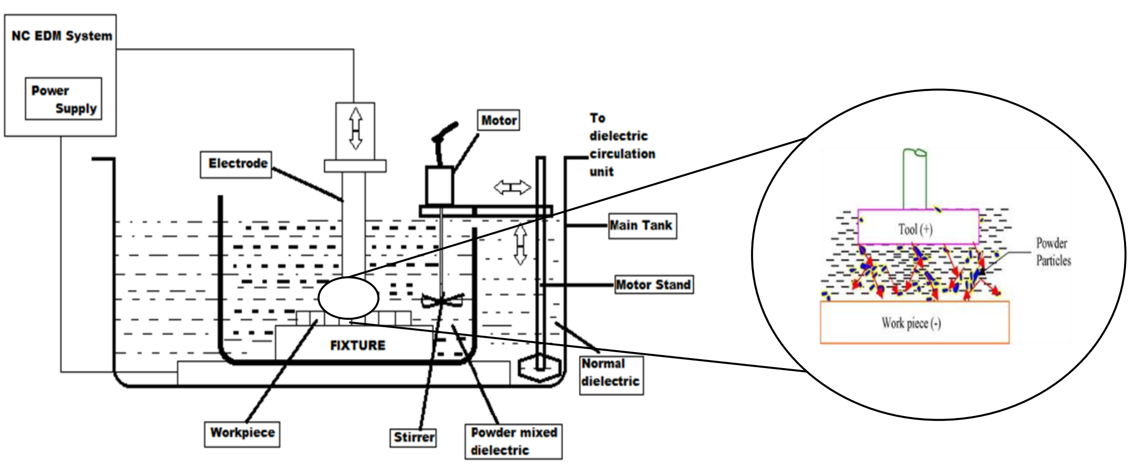

Fig. 1: Schematic diagram of machining set-up and principle of powder-mixed EDM

3. LITERATURE REVIEW

Kobayashi et al. [5] investigated the effects of suspended powder in dielectric fluid on surface roughness. It was reported that the surface finish of SKD-61 material is improved with the use of silicon powder. Narumiya et al. [6] found that aluminium and graphite powders yield a better surface finish than the silicon powder. Mohri et al. [7] reported the effect of silicon powder addition into dielectric fluid on the surface finish of H-13 die steel. The fine and corrosion-resistant surfaces having roughness of the order of 2 µm were produced. Pecas and Henriques [8] investigated the influence of silicon powder mixed dielectric on conventional EDM. The results show that by the addition of 2 g/l silicon powder, the operating time and surface roughness decrease. The surface roughness varies from 0.09 to 0.57 μm for the area range of 1 cm^2 to 64 cm^2. Wong et al. [9] studied the near-mirror-finish phenomenon in EDM using fine powder (silicon, graphite, molybdenum, aluminium, and silicon carbide) mixed dielectric. Zhao et al. [10] investigated that PMEDM improves the machining efficiency and surface roughness by selecting proper discharging parameters. Further, when peak current increases the surface roughness becomes lower. Ming and He [11] reported that the additives (conductive and inorganic oxide particles) increase the MR, decrease the TWR, and improve the surface quality of the workpiece quite effectively. Uno and Okada [12] investigated the effect of silicon powder mixing on the surface generation mechanism. The EDM with silicon powder mixed fluid produced glossier surfaces as compared to those produced by conventional EDM with kerosene fluid. It was argued that EDM with silicon powder mixed fluid led to smaller undulation of a crater because the impact force acting on the workpiece is smaller. This results in the stable machining without a short-circuit between the electrode and the workpiece. Patel et al. [13] investigated the influence of parametric setting on machining performance during EDM of $Al_2O_3/SiC_w/TiC$ ceramic composite. He observed that pulse on time influences the SR more predominantly than other factors due the fact that any increase in the pulse-on time increases the plasma channel diameter that reduces both energy density and impulsive force.

4. MATERIALS AND METHODS

Aluminum alloy 6063 was employed as the workpiece material. The Chemical Composition of the Al6063 are presented in Table 1. A Copper tool electrode (5mm diameter) as shown in fig. 2 was used in this study. The Silicon powder was selected as the additive for performing PMEDM experiments. A die sinking EDM machine of Electronica powered by a 35 Amp pulse generator

Table 1: Chemical Composition of Al6063 alloy

Workpiece Material	Chemical Composition (Wt %)								
Al6063 alloy	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
	Max 97.5	Max 0.1	Max 0.1	Max 0.35	0.45-0.90	Max 0.1	0.2-0.6	Max 0.1	Max 0.1

Fig. 2: Tool – Copper electrode

was employed for conducting the experiments.. An experimental setup for PMEDM has been designed and developed in the laboratory Peak current, duty cycle, Silicon powder concentration and pulse on time were decided as input parameters. MRR, SR and TWR was chosen as the performance measures. MRR and TWR was calculated from the standard formula by weighing the workpiece on digital electronic weighing balance having least count of 0.001mg before and after machining. The SR was evaluated by a Mitutoyo surface roughness tester.

4. RESULTS AND DISCUSSIONS

One variable at a time approach is considered for this experimentation i.e. only one variable at a time is evaluated keeping all others variables constant during a test run. The process parameters taken for the present study is given in table 2.

Table – 2: Parameters of the experiment

Workpiece Material	Electrode Material	Machining Parameters Range	Response Parameters
Aluminium 6063 alloy	Copper	Current : 1-10 A Pulse On:10-100 μs Duty Cycle: 0.72 % Powder Conc. :0-12 g/l	MRR , TWR, SR

4. 1 Effect of peak current on Performance Measures

Fig. 3 shows that MRR increases proportionally with peak current for all values of pulse on time. This mainly occurs due to increase in sparking efficiency with increment of peak current, which produces the higher temperature, causing more material to melt and erode from the workpiece. It has been noticed that the MRR increases gradually up to 7 ampere peak current, thereafter MRR increases slowly with further increase in peak current. With high range of current, more sparks is produced which results in formation of more debris.

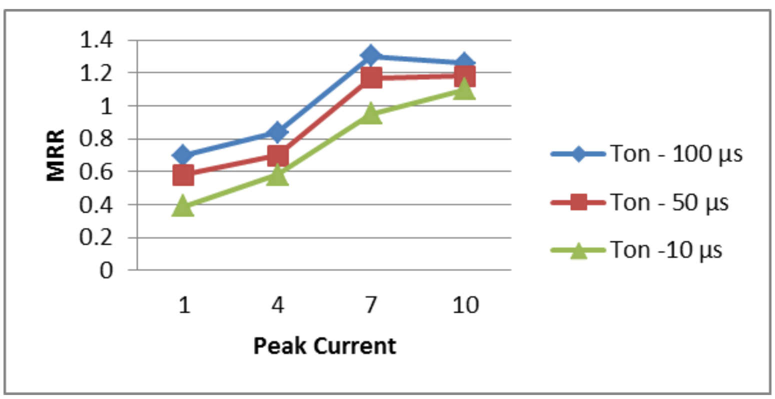

Fig. 3: Effect of peak current on MRR

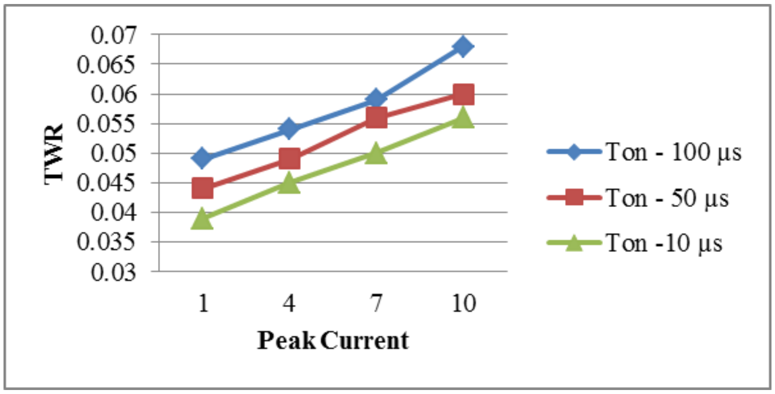

Fig. 4: Effect of peak current on TWR

Fig. 4 shows that TWR increases with the increase in peak current. This occurs due to higher temperature at high values of peak current. This higher temperature causes more material to melt and erode from the electrode. Fig. 5 shows that SR also increases with increase in peak current.

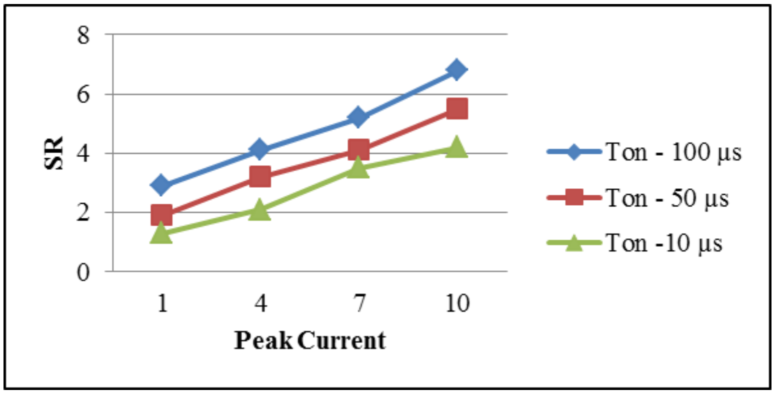

Fig. 5: Effect of peak current on SR

4.3 Effect of Powder Concentration on Performance Measures

Fig. 6 shows that with the increase in powder concentration, MRR also increases. Maximum MRR is obtained with the increment in the powder concentration whereas TWR decreases with increase in powder concentration as shown in fig.7**.**

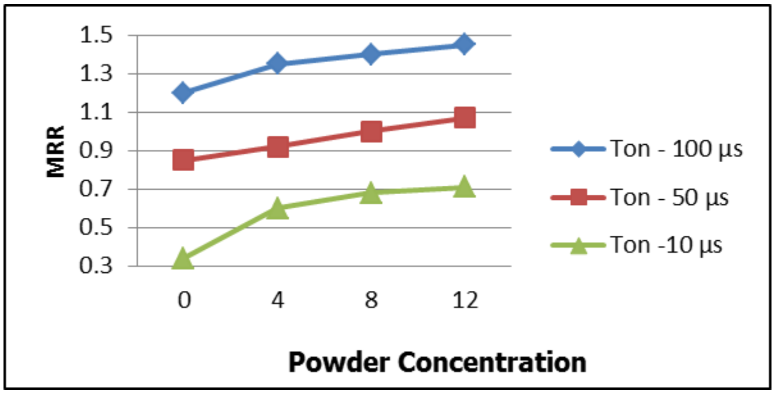

Fig. 6: Effect of powder concentration on MRR

Fig. 8 shows that the powder concentration significantly affects the SR. It has been noticed that the increase of powder concentration up to 8g/l results in decrease in surface roughness, thereafter it starts increasing. The added powder enlarged and widened the plasma channel. Even distribution of sparking among the powder particles leads to reduction in electric density of the spark. Therefore, flat craters are formed on the workpiece surface. Hence the surface roughness is reduced.

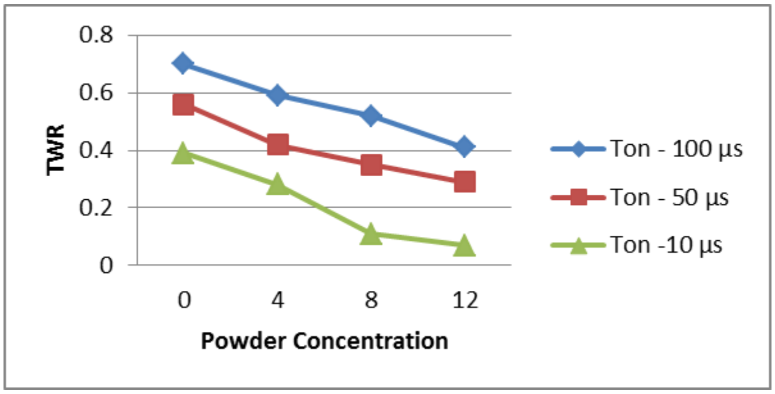

Fig. 7: Effect of powder concentration on TWR

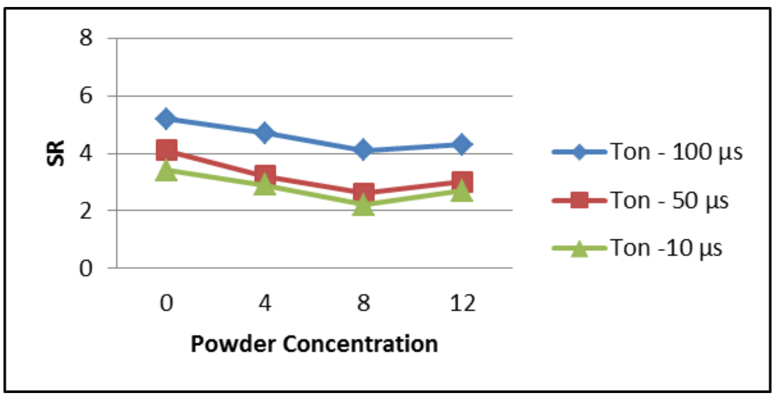

Fig. 8: Effect of powder concentration on SR

5. CONCLUSIONS

The specific conclusions drawn from the present research work are as follows:

1. It has been concluded that the peak current and powder concentration plays significant role against MRR, TWR and SR. It has been analyzed that the increase in peak current leads to an increase in MRR, TWR and SR.
2. The addition of silicon powder into the dielectric fluid of EDM leads to reduction in SR and TWR, whereas MRR increases. The SR is reduced up to 8g/l, thereafter it starts increases, because higher amount of powder particles might clog the spark gap and results in arcing.

6. REFERENCES

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