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Surface Morphology of Die-Steel Machined with Al Powder Mixed Distilled Water and Kerosene in Edm – A Comparison

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Abstract : In this paper, an attempt has been made to compare the effect of Al powder mixed distilled water and kerosene dielectric fluids with respect to white-layer thickness (WLT) and surface morphology. The work and tool electrode materials used are W300 die-steel and electrolytic copper respectively. Pulse peak current, pulse on-time and concentration of Al powder are taken as the process parameters to study white-layer thickness. The experiments are planned using face centred central composite design procedure (FCCCD). From the experimental results it is found that, better surface morphology obtained at 4 g/l of Al in kerosene at high peak current of 18 A.
Keywords : PMEDM, Distilled water, Kerosene, Al powder, W300 die-steel, SEM.

1. Introduction

Dielectric fluids fulfil an important function on which, productivity, cost and quality of the machined parts depends. In addition to maximizing quality and cost, it is imperative for the manufacturing industries to be concerned with minimizing environmental impact. To that end, research is continuously being done over three decades to improve the process efficiency by alternative dielectric fluids such as pure water, water mixed with organic compounds and commercial water-based dielectric fluids. Several researchers have attempted in modifying the EDM process to alleviate some of these constraints using powder-mixed hydrocarbon oils (PMEDM).

During PMEDM investigation using various powders of Graphite, Al, Si, SiC, Crushed glass, MoS_2, Al powder produced near mirror whereas graphite and Si resulted in glossy finish surfaces on the AISI-O1, SKH54 steels [1]. Increase in the concentration of Ni powder in the kerosene, the recast layer became more uniform and thick during the machining of aluminium-bronze [2]. Type of powder suspended in the dielectric fluid also found to influence the spark gap, which is more for Al powder when compared to others, Due to this Al powder resulted in good surface finish. Further, addition of powders found to reduce white-layer thickness [5]. In order to prevent the agglomeration of powders during machining in PMEDM, surfactant molecules (Polyoxythylene-20-sorbitan monooleate) in dielectric fluid also tried [6].

Suspension of carbon nano-tube (CNT) in the dielectric fluid resulted in reduced micro-cracks and better surface morphology when compared with pure dielectric fluid [7]. Addition of graphite nono-powder (55 nm), the metal removal rate increased by 35%, micro-crack density reduced from 0.03 /cm to 0.004 /cm and surface roughness value reduced from 1.8 μm to 1.4 μm when compared to pure dielectric fluid [8].

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Even though addition of metallic powders to oil based dielectric fluids found be advantageous and efficient over EDM, less work is done on powder mixed water-based dielectric fluids. In the case of water-based dielectric fluids, studies are limited to organic additives. Glycerine solution yields reduced surface roughness values as compared to Electrical discharge machining of 56NiCrMoV7 [9] using hydro carbon oils. In a similar study, urea mixed in water resulted in the formation of hard TiN layer due to element transfer during machining of Ti alloy [10].

During the comparative studies it is found that EDM oil increased the carbon content of the white-layer, whereas water resulted in decarburization and less micro-cracks on the white-layer[11]. During machining of Ti-6A-4V, TiClayer formed with kerosene and TiO layer with distilled water distilled water dielectric fluids[12]. It is also found that machining with de-ionized water the intensity of micro-cracks are less in the white-layer than the base material [13].

In addition to the organic compounds, additions of B_4C abrasive powder mixed water found to improve the surface quality and reduce the WLT on Ti-6Al-4V when compared to pure water [16]. Extensive comparative studies showed that, Emulsion dielectric fluids resulted in high value of surface roughness, WLT and micro-hardness when compared to kerosene or de-ionized water. Whereas machining with water resulted in shallow micro-cracks[17].

From the above studies, it is evident that powder addition to the dielectric fluids resulted in machined surface with less micro-cracks with required surface modification.

2. Experimentation

The experiments were conducted on a die sinking EDM machine with a separate dielectric recirculation system fabricated and attached to the machine. The recirculation system consists of dielectric tank, pump and delivery devices. Figure 1 shows the close-up view of fixture - workpiece assembly. The work material chosen for the present study is W300 die-steel. The work pieces were wire-cut to the required size and the top and bottom surfaces were ground to maintain similar R_a values and flatness. The tool electrode is a solid rod of 9.5 mm diameter made of Electrolytic copper.

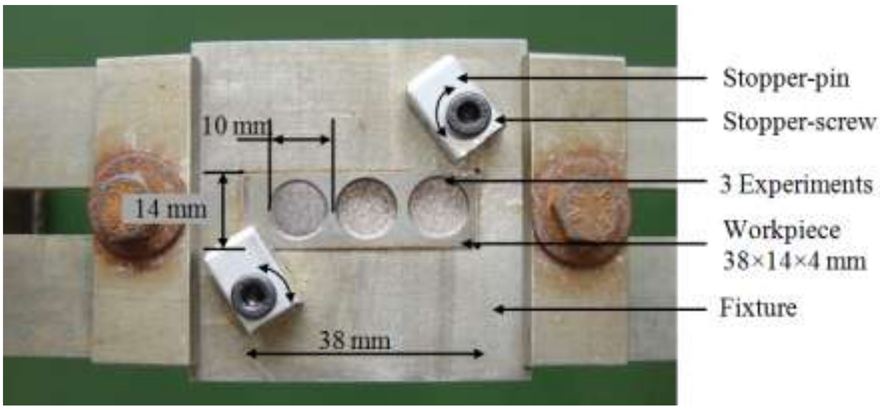


Fig. 1.Close-up view of fixture - workpiece assembly.

3. Selection of PMEDM Process Parameters

In PMEDM, process parameters are classified into various groups such as electrical, non-electrical, powder, dielectric fluid and electrode parameters, and dielectric fluid. The most influencing parameters such as peak current (I), pulse on-time (T_{on}), duty factor (DF), gap voltage (V), Polarity (P), concentration of the powder (C) and size of the powder (S) are identified for the present work.

The levels of the process parameters were selected by conducting pilot experiments, literature survey and from the machine manual. Negative polarity (NP) was selected for kerosene and positive polarity (PP) for distilled water which resulted in high MRR. Peak current is varied from 6 - 18 A. A gap voltage of 40 V was selected for the experiments for stable machining condition.

Pilot experiments it is found that, concentration level more than 6 g/l of Al powder causes frequent short circuits and makes machining process unstable. Hence, a maximum concentration of 4 g/l was selected. The coded and the actual values of these process parameters are shown in the Table 1. The process parameters maintained at a fixed value are shown in the Table 2.

Table 1.Process Parameters (FCCCD).

Process parameters	Unit	Levels		
		-1	**0**	**1**
Peak current (*I*)	A	6	12	18
Pulse on-time (T_{on})	µs	120	220	320
Concentration of powder (*C*)	g/l	0	2	4

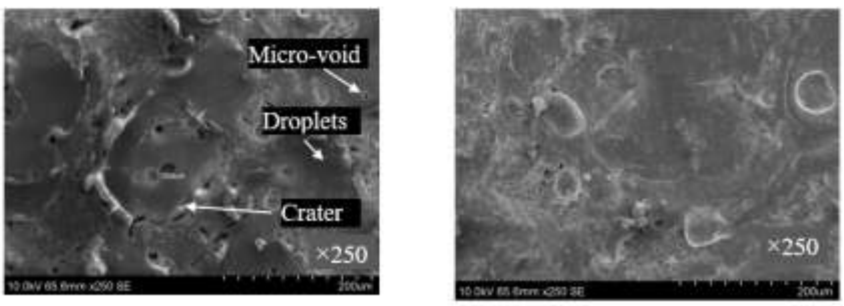
Table 2.Values of the Fixed Process Parameters.

Fixed process parameter	Value
Voltage (V)	40 V
Duty factor (DF)	65%
Powder size (S)	27 μm
Flushing pressure	70(kPa)
Polarity (P)	Distilled water - PP Kerosene - NP

4. Results and Discussion

Scanning Electron Micrographic Analysis

The characteristics of the recast layer formed on W300 die-steel machined using aluminium powder-mixed distilled water were compared with the samples machined with kerosene dielectric fluid. Scanning electron microscopy (SEM) was performed to study the surface topography of the samples. SEM topography reveals that the machined surface is covered with shallow craters, globules of debris, micro voids and cracks due to the sparking process. The shape of crater and voids has shown a correspondence with the type of dielectric liquid which is analogous with optical micrographic analysis of the white-layer. The appearance of the white-layer formed with distilled water is easily distinguished from the white-layer obtained with kerosene dielectric fluid.



(a) I - 6 A, T_{on} - 120 μs, C - 4 g/l. (b) I - 12 A,T_{on} - 220 μs, C -0 g/l.

Fig. 2. SEM micrographs, dielectric: distilled water.

Figure 2(a) shows the scanning electron micrographs of W300 die-steel machined with high concentration (4 g/l) Al powder-mixed distilled water at low current (6 A) and low pulse on-time (120 μs) at different magnifications at ×250. It is evident from the figure that high concentration of Al powder leads to deeper cracks (Figure 2.a) and micro-voids on the white-layer. These results are in line with the work done by other investigators[12, 17]. High cooling rate of distilled water resulted in micro-cracks on the machined surface when compared to kerosene dielectric fluid. Whilst, at medium currents with pure distilled water produces dense recast layer with less cracks as shown in figure 2(b).

Figure 3(a) shows the scanning electron micrographs of W300 die-steel machined with high concentration Al powder (4 g/l) mixed kerosene at high current (18 A) and low pulse on-time (120 μs) at ×50 magnifications. When powders are added to the dielectric fluid multiple discharging effects were created [15]. At high pulse currents, these energies are sufficient enough to melt and evaporate the work surface producing uniform craters with better surface morphology. Whilst, low currents results in non-uniformities on the machined surface due to improper melting evaporation (Figure 3b). The effect of pure kerosene without the addition of aluminium powder can be clearly seen in the Figs.3 (c-d) machined different pulse currents. The surface is covered with carbon deposits from the kerosene dielectric fluid and fine debris at high pulse current of 18 A whereas improper melting, and resolidified white-layer at low pulse currents of 6 A.

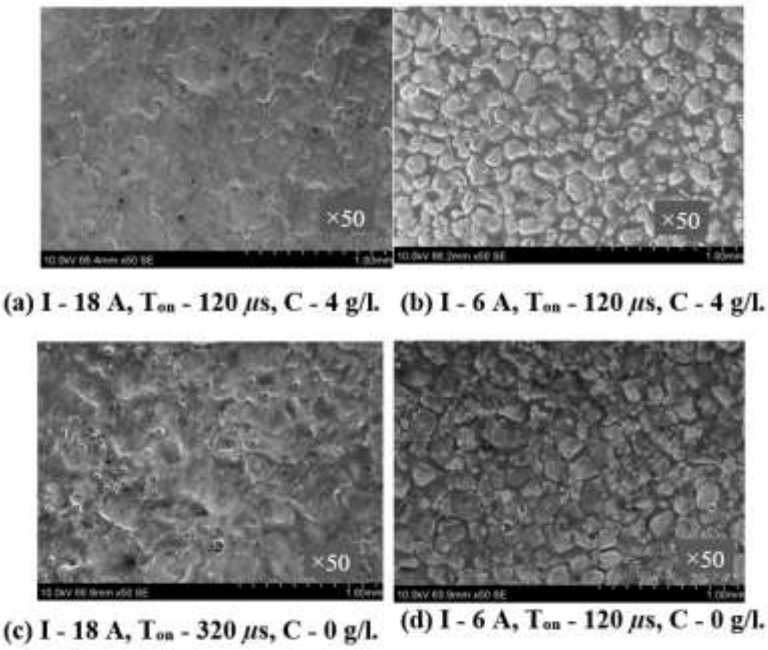


Fig. 3. SEM micrographs - Material: W300 die-steel, Electrode: Cu, Polarity – NP, dielectric: kerosene.

4. Conclusion

The factors peak current, pulse on-time and concentration of the Al powder have significant contribution on the surface morphology of the machined samples. Better surface morphology obtained at 4 g/l of Al in kerosene at high peak current of 18A when compared to Al powder mixed distilled water.

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