

Improving machining performance using alumina powder-added dielectric during electrical discharge machining (EDM)

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Abstract. Alumina powder was added to dielectric fluid during Electrical discharge machining (EDM) of AISI 304 steel. The main machining parameters of current (A), tool diameter (mm) and powder concentration (g/L) were chosen to determine the EDM machining characteristics of material removal rate (MRR), tool wear rate (TWR) and surface roughness (Ra). This work adopted two-level full factorial experiments. The significant factors that affect the MRR and tool TWR are current, tool diameter and powder concentration. The MRR increases when the current and tool diameter are higher. The presence of powder concentration also increases the MRR. The higher current used and the presence of powder concentration increase the TWR. Meanwhile, a smaller tool diameter gives higher value of TWR. Current and powder concentration are the significant factors to determine the surface roughness of work surfaces. Higher current applied gives high surface roughness, but higher powder concentration gives improved surface finish.

1. Introduction

Electrical discharge machining (EDM) is a unique technique of machining electrically conductive materials with using a series of electrical sparks between the electrode and workpiece. During electric sparks temperature rises from 8,000 to 20,000 °C sufficient to melt and vaporize any work material. One of the recent developments in EDM is powder mixed EDM (PMEDM). PMEDM can distinctly improve the surface finish and surface quality to obtain near mirror-like surfaces at relatively high machining rate. Ming and He [1] stated that when kerosene is mixed with some additive powder during EDM, the material removal rate (MRR) will increase. Addictive can increase the discharge gap, lower the discharge voltage and make the discharging current more even. It was concluded that PMEDM will affect the gap distance between electrodes. It was reported that higher conductivity of dielectric will easily collapse the insulating strength thus extends the gap distance. Pecas and Henriques [2] observed an improvement in the performance of conventional EDM when used with a powder-mixed dielectric. The additives with different thermo-physical properties, including aluminum (Al), chromium (Cr), copper (Cu), and silicon carbide (SiC) were studied. The particle size of additives in the dielectric oil influences the surface quality of EDM work. The smallest particles (70-80 nm) give better surface finish of machined work, the bigger the particle size leads to poor improvement of surface roughness. However, particle size has opposite impact on the recast layer. Kumar et al. [3] reported that when the aluminum particle suspended in the dielectric fluid, it makes



uniform of the discharging energy dispersion; it displays multiple discharging effects within a single input pulse in the PMEDM. In the present study the work material, the electrode material and additive powder were AISI 304 steel, copper and alumina respectively.

2. Experimental Procedure.

The main composition of the workpiece material AISI 304 steel is: Cr: 18-20%; Ni: 8-10.5%; Mn: 2.0%; Si: 1.0%; C: 0.08%; P: 0.04% and S: 0.03%. Its physical properties include hardness 187 HB; density $7.9 \times 10^3 \text{ kg/m}^3$; melting point 1400-1455 °C; thermal conductivity $48 \text{ Wm}^{-1}\text{K}^{-1}$ and yield strength 207 MPa. The main characteristics of copper electrode were: density $8.96 \text{ g}\cdot\text{cm}^3$; melting point 1084.62 °C, boiling point 2562 °C and electrical resistivity $1.96 \mu\Omega \text{ cm}$. Properties of alumina were: sizes 30-45 microns; density $3.95\text{-}4.1 \text{ g/cm}^3$, melting point 2072 °C and boiling point 2977 °C. Kerosene was used as dielectric fluid. Experiments were conducted on MITSUBISHI EX 22 die-sinking EDM machine. Work surface roughness was measured using Mitutoyo SURFTEST SV.500. Weight of the workpiece and the electrode before and after each machining was measured by an electronic balance. Experiments were conducted using two-level full factorial design.

3. Results and Discussions

In this study, two-level full factorial design was used to plan and analyze the experiments. The detailed plan of the experiments is shown in Table 1. Current, tool diameter and powder concentration were taken as the input parameters while MRR, TWR and Ra were the responses.

Table 1: Experimental plan for the investigation

Std	Run	Block	Factor 1 A: A current	Factor 2 B: tool diameter mm	Factor 3 C: powder con g/L	Response 1 MRR g/min	Response 2 TWR g/min	Response 3 Ra micrometer
6	1	Block 1	6.5	14	3			
	2	Block 1	6.5	14	0			
	3	Block 1	2.5	20	0			
	4	Block 1	2.5	14	0			
	5	Block 1	2.5	14	3			
	6	Block 1	6.5	20	0			
	7	Block 1	2.5	20	3			
	8	Block 1	6.5	20	3			

3.1 Material Removal Rate (MRR).

Influence of current and electrode diameter on MRR are shown in Fig.1. The higher current applied will increase the value of MRR. This is due to the fact that sparks with more energy are generated during machining that would assist to remove more material from the workpiece. So, the relationship between current and MRR is directly proportional. This finding agrees with the research done by Abbas et al. [4]. When the tool diameter area is large, the heat loss to surrounding is less compared to small area. This results the MRR value to be higher when large tool diameter is used.

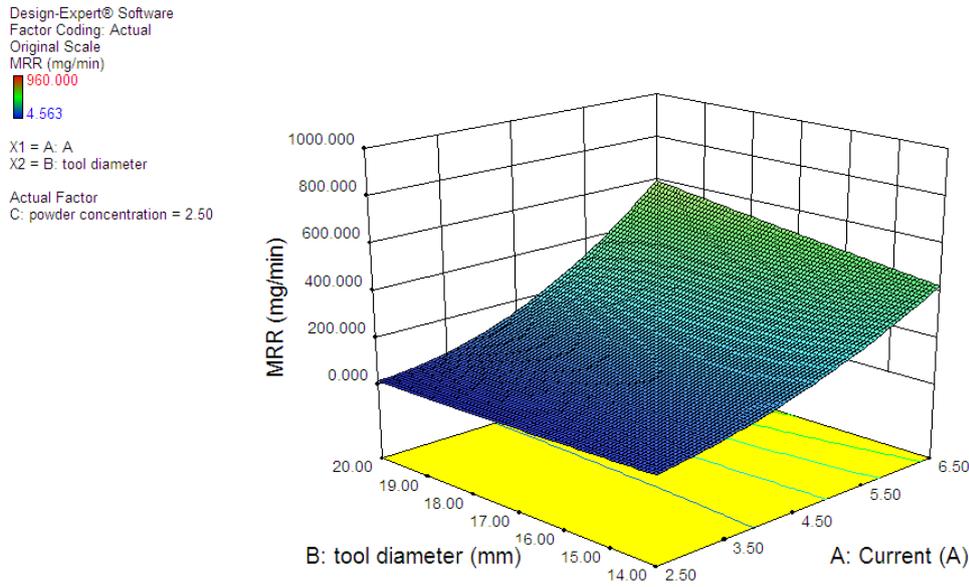


Fig.1: 3D surface plot for MRR as a function of the tool diameter and current

The relationship of current and powder concentration on MRR is presented in Fig.2. It is evident from the Fig.2 that increase in powder concentration facilitates MRR. Increase in powder concentration breaks down the main plasma channel into small sparks. As a result spark is distributed over the machining zone more evenly and thus increasing MRR.

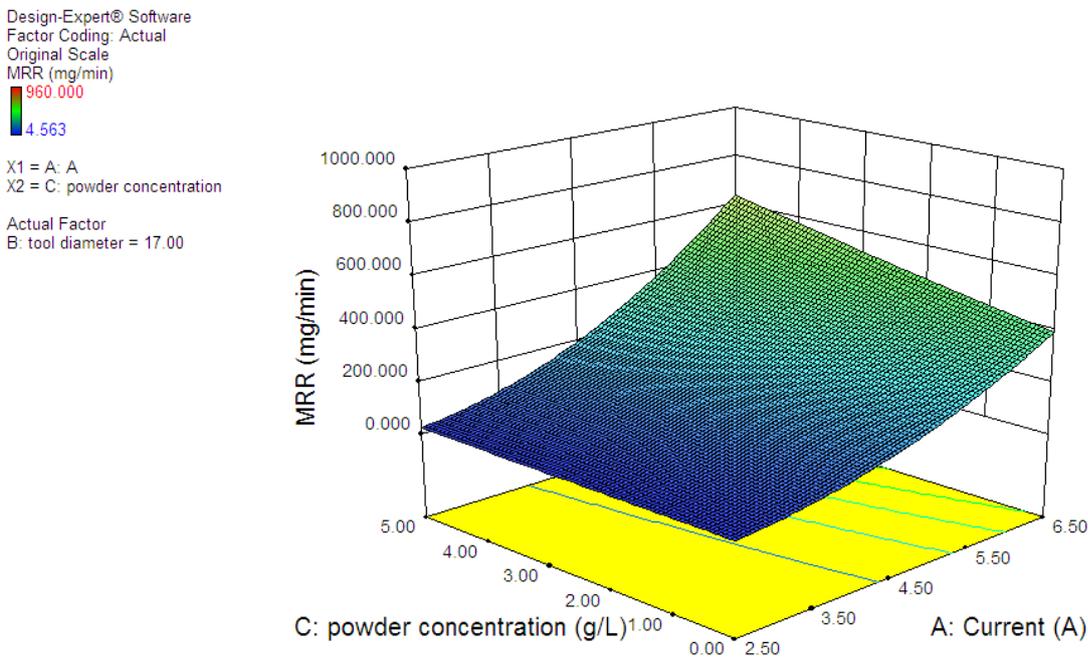


Fig.2: 3D surface plot for MRR as a function of the powder concentration and current

3.2. Tool Wear Rate (TWR).

The higher current applied will result in higher value of TWR. This was due to the fact that more heat was generated with a higher value of current that produced high intensity of sparks which in turn caused the tool material to be removed from the surface. The relationship between current and tool diameter on TWR is illustrated in Fig.3. Current and TWR are almost directly proportional. However, the relationship between tool diameter and TWR was inversely proportional at high level of current. The lower tool diameter, higher will be the higher value of TWR. When the diameter is smaller, energy concentration is more and more material is removed from the tool material.

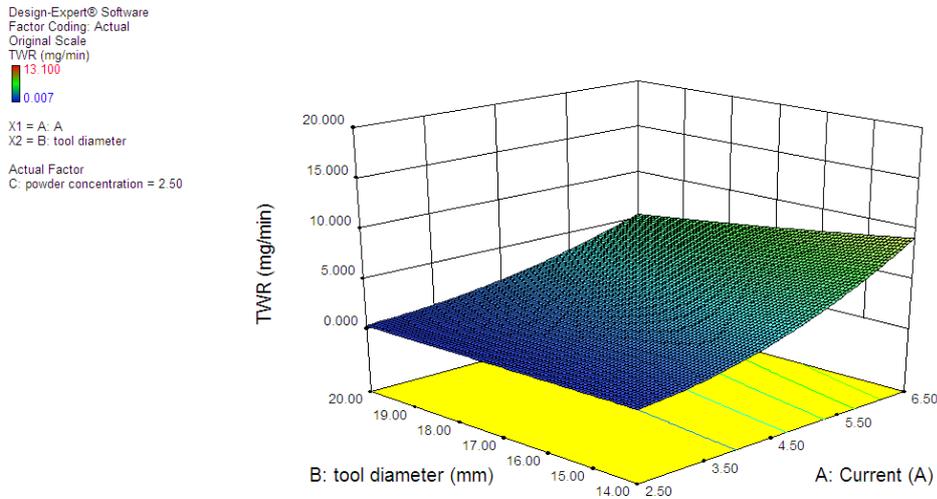


Fig.3: 3D surface plot for TWR as a function of tool diameter and current

However, with increase in powder concentration TWR reduces (Fig.4). Powder concentration increases the spark gap and improves flashing away of the machined debris from the machining zone and facilitates cooling of the electrode. As a result TWR decreases.

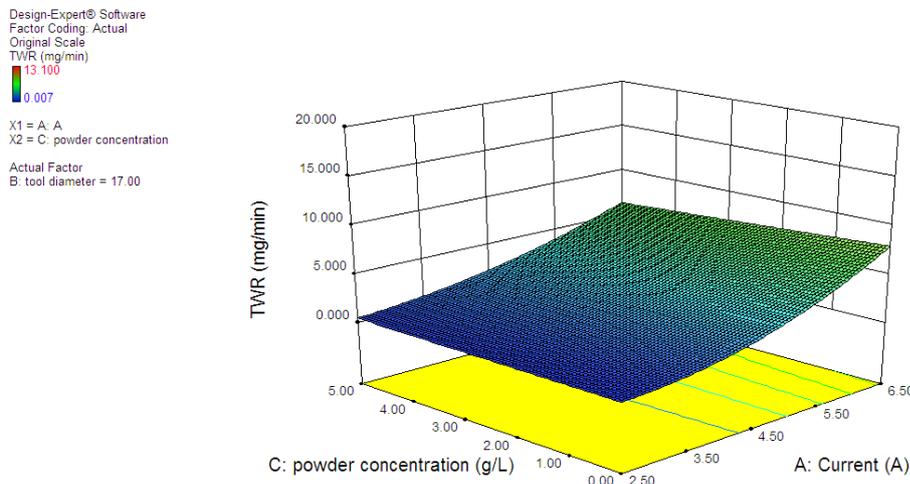


Fig.4: 3D surface plot for TWR as a function of powder concentration and current

3.3. Surface Roughness (Ra).

The higher current applied increases the value of surface roughness which means poorer surface condition. The intensity of sparks increases due to high current which produces deeper craters and makes the work surface rougher (Fig.5). Similarly, a higher diameter of the electrode shows poor surface finish. With increase in diameter of the tool, flashing of the dielectric becomes poorer and more debris is deposited on the surface and the surface becomes rougher. From Fig.6 it can be observed that higher concentration of powder improves work surface finish. The higher the concentration of powder, the more scattered will the spark discharge be and the smaller will the craters be on the surface.

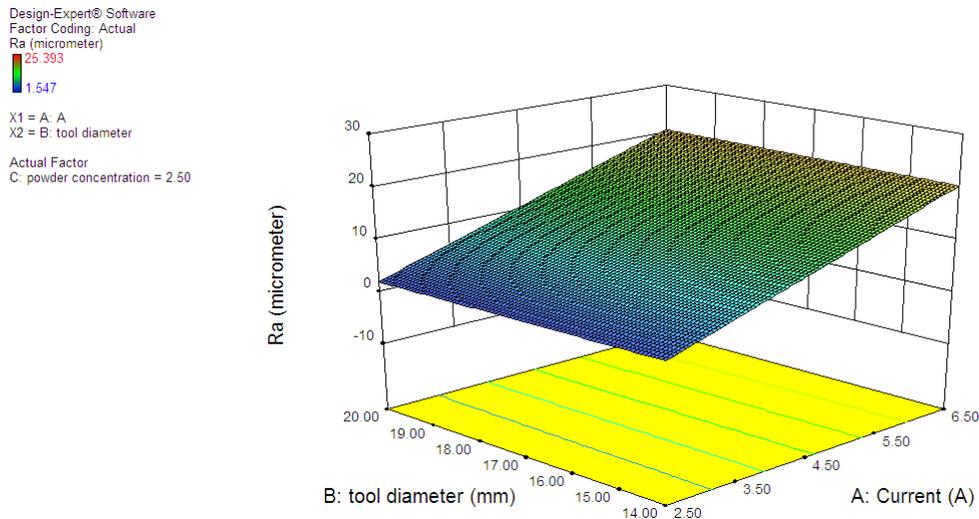


Fig.5: 3D surface plot for Ra as a function of tool diameter and current

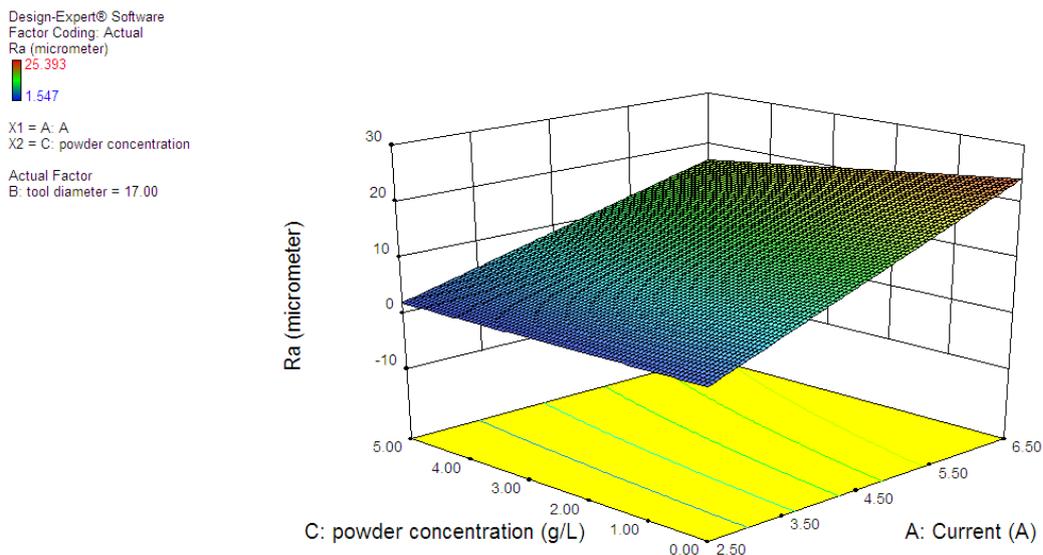


Fig.6: 3D surface plot for Ra as a function of powder concentration and current

4. Conclusion

EDM was done on AISI 304 steel with current, electrode diameter and alumina concentration in the dielectric as variables. It was found that MRR, Ra and TWR increase with increase in current. With increase in electrode diameter MRR and Ra increase, but TWR reduces. Alumina powder addition to dielectric shows significant improvement in EDM, since it causes increase in MRR, but reduces TWR and Ra.

Acknowledgments

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