Enhanced surface roughness of AISI D2 steel machined using nano-powder mixed electrical discharge machining

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ABSTRACT – Manufacturing geometrically complex components with high strength and high wear resistance is an essential requirement in fabricating heavy-duty industrial components. Electrical Discharge Machining (EDM) is a non-conventional machining technique with the potential to machine any conductive material regardless of hardness property. This experiment concentrates on Powder Mixed EDM (PMEDM), where a specific concentration of titanium powder is added to the dielectric. The effect of adding powder is investigated on machined surface roughness. It is revealed that for 120 μsec and 210 μsec spark durations, the impact of titanium particles significantly improves the R_a and R_z of the AISI D2 steel machined surface. However, increasing the spark duration to 340 μsec leads to surface roughness deterioration owing to debris particles adhering onto the surface.

1. INTRODUCTION

Production of durable machineries with complex shape is a crucial necessity in heavy-duty manufacturing industries. Electrical Discharge Machining is an advanced engineering machine implemented in various industries, including die and mold production, and the automotive, aerospace, biomedicine as well as communications fields. Several attempts have been made to enhance EDM performance, but Powder Mixed EDM (PMEDM), which entails adding powder to a dielectric fluid, is the most practiced approach. By emphasizing on the surface roughness produced, an attempt is made to investigate the influence of adding titanium powder on the formed surface.

2. METHODOLOGY

The equipment used is SODICK die-sinking EDM upgraded with an external dielectric circulation system that enables utilizing the powder-added dielectric in the process. Figure 1 schematically demonstrates the developed apparatus including the machining chamber, pump, filter, pressure gauge, pipe, nozzle, valve, etc.
Copper and AISI D2 steel were selected as the tool and workpiece materials, respectively. Table 1 represents the experimental parameters.

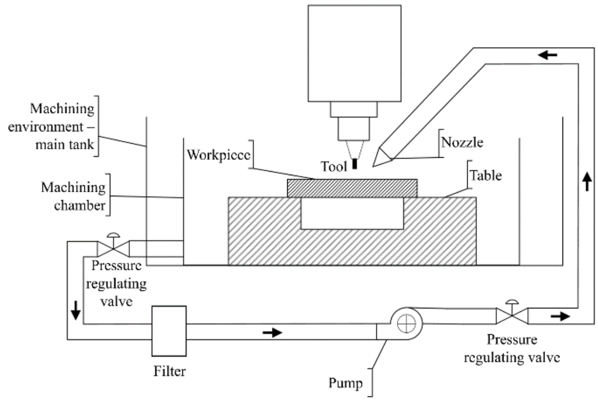

Figure 1 PMEDM external dielectric circulation system.

Table 1 Experimental machining parameters.

T_{on} (μsec)-T_{off} (μsec)	120-80, 210-140, 340-225
Duty Factor (%)	~ 60
Peak Current (A)	6, 12, 20
Voltage (V)	120
Powder material	Titanium
Powder size (nm)	40-60
Concentration (g/l)	1

3. RESULTS AND DISCUSSION

Figure 2 shows an example of surface roughness measurements for 12 A peak current, with and without titanium powder. R_a represents the average surface roughness and R_z is the maximum peak-to-valley distance in the measured length. R_z reflects the extreme points on the surface, which may nullify in the average surface roughness. According to the results, both R_a and R_z improve when using Ti-mixed dielectric at 120 μsec and 210 μsec discharge durations. The greatest improvement was observed for both R_a and R_z at 210 μsec discharge interval. R_a and R_z improved 34.83% and 40.11% at 12 A and 20 A peak current, respectively. Furthermore, R_z exhibited greater enhancement than R_a when using titanium additive, which specifies the significant reduction of extreme peak and valley points on the machined surface.

As shown in Figure 3, the contribution of conductive titanium powder widens the discharge gap due to the improved electrical conductivity of the dielectric. Hence, discharge occurs further from the surface, resulting in shallower craters. Additionally, unlike EDM, sparks do not directly strike the workpiece surface in PMEDM due to the presence of powder particles in the machining area. The initial discharge occurs between the tool and powder particles and the series of smaller sparks hit the workpiece [1]. Therefore, lower ridge levels lead to lower surface roughness when using titanium added to oil owing to different discharge mechanisms in the machining gap.

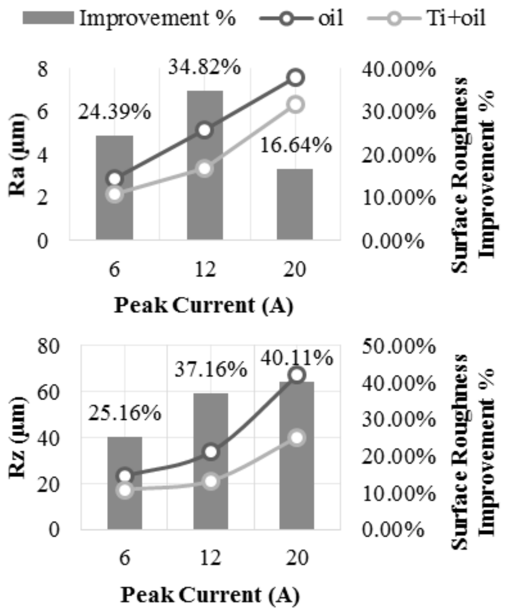

Figure 2 R_a and R_z at T_{on}=210 µsec and T_{off}=140 µsec, with and without titanium powder.

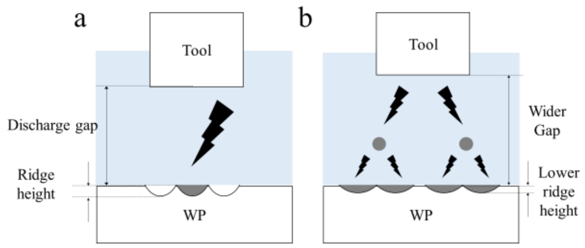

Figure 3 Spark mechanism in (a) EDM, and (b) PMEDM.

With increasing the spark duration to 340 µsec, the surface roughness trend completely varies from lower spark intervals. At 6 A peak current, the Ti powder improves the surface roughness. However, surface roughness increases at 12 A and 20 peak current. As shown in Figure 4, the existence of black spots on the machined surface led to a surface with greater roughness due to debris particles adhering to the surface. Higher density of Ti-mixed dielectric compared with oil associated with the development of large debris particles in this machining condition resulted in lower dielectric flow. Less dielectric flow rate in the gap, leading to more difficult ejection of debris particles. The debris entrapped in the gap reduced the surface quality compared with EDM oil.

4. CONCLUSIONS

The machined surface roughness under titanium-added EDM condition significantly enhanced at 120 and 210 µsec discharge durations due to the increased dielectric conductivity and different discharge attributes which leads to formation of shallower craters on the surface. Conversely, for 340 µsec discharge duration, the surface roughness deteriorated owing to the heavy debris particles adhering to the surface.

5. ACKNOWLEDGEMENTS

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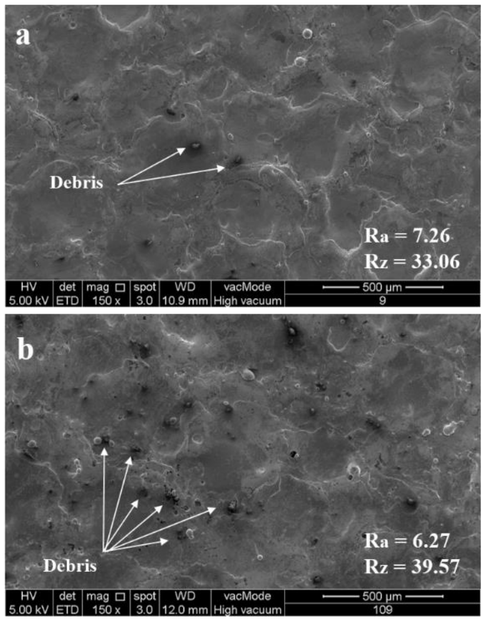

Figure 4 FESEM micrograph of machined surface with T_{on}=340 µsec and I=20 A for (a) oil and (b) Ti added to oil dielectric.

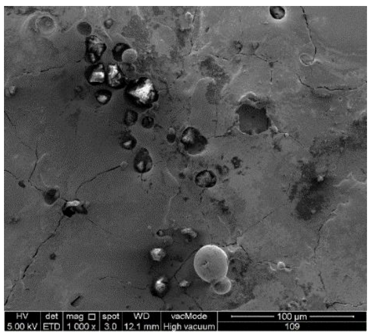

Figure 5 Surface micrograph, T_{on}=340 µsec, I=20 A and Ti added to oil dielectric.

6. REFERENCES

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