

A Comparative Study on Machining Performance of wet EDM, Near Dry EDM and Powder Mixed Near Dry EDM

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Abstract

Electrical discharge machine (EDM) is a well-known non-contact machining technique in the presence of dielectric medium. The dielectric medium plays an important role on the machining performance of EDM. In this study, effect of different dielectric mediums were studied on the machine performance of wet EDM, near dry EDM (ND-EDM) and powder mixed near dry EDM (PMND-EDM). Machining performance such as material removal rate (*MRR*), tool wear rate (*TWR*) and surface roughness (*SR*) were selected with five different dielectric medium such as deionized water for wet EDM, deionized water-air for ND-EDM, deionized water-air-graphite powder, deionized water-air-manganese powder & deionized water-air-silicon carbide (SiC) powder for PMND-EDM. It is observed that wet EDM has highest *MRR*, *TWR* and *SR*. PMND-EDM has lowest *TWR* and *SR*.

Keywords: ND-EDM, PMND-EDM; *MRR*; *TWR*; *SR*

INTRODUCTION

Electrical discharge machine (EDM) is a well-known non-contact machining technique for cutting complex and precise geometric shapes material components which is difficult to cut by conventional machining process. It is mainly used to manufacture the dies & molds and also to manufacture the components of medical, defense, aerospace and automobile etc. The gap between the workpiece and tool is filled with the dielectric medium as an insulator. A gap voltage is applied at the inter electrode gap (IEG) between the workpiece and tool for subjecting an electric field. Increase in gap voltage increases the intensity of the electric field reaches more than the dielectric strength, which breaks down the dielectric medium and ionization take place. Thus, plasma channel is formed and produced the discharges (sparks) between the electrodes, as a result thermal energy is generated at high temperature of 8000-12000°C. The temperature is enough to remove the material from the workpiece in the form of tiny carters by repeated melting and vapourization. Moreover, dielectric medium plays an important role in the dispersion of plasma channel, erosion of material, removal of debris by flushing, refreshing of the IEG and also as a coolant. EDM with liquid dielectric medium simply known as wet or conventional EDM is widely used in precision machining process. Hydrocarbon oil and deionized water are well known single-

phase liquid dielectric mediums used in wet EDM [1]. Hydrocarbon oils such as transformer oil, kerosene, mineral oils and mineral seals have high aging resistance and non-corrosive properties. However, it releases the carcinogenic substances like benzopyrene (C₂₀H₁₂) and benzene (C₆H₆) [2]. Moreover, low surface finish (*SR*), higher tool wear rate (*TWR*) and environmental hazards limited the wider application of wet EDM.

Thus, many researchers have focus on different dielectric medium to diminish the limitation of wet EDM. Kunieda and Yoshida [3] have proposed dry EDM which used gas as dielectric medium instead of liquid medium and observed negligible *TWR* with minimum environmental hazards. Air and oxygen are commonly used gas dielectric medium in dry EDM. However, low material removal rate (*MRR*) and low surface quality due to debris reattachment were the major limitation of the dry EDM. Consequently, it is imperative to study the other two-phase (liquid-gas) dielectric medium for near dry EDM (ND-EDM) and three-phase (liquid-gas-solid powder) dielectric medium for powder mixed near dry EDM (PMND-EDM) to improve the machining performance. A brief literature has been analyzed on the different dielectric medium and summarized as follows.

Use of deionized water improved the *MRR* and reduces the *SR* and *TWR* as compared to the kerosene [4]. Moreover, it reduces the adhesion of carbon on the surfaces of electrode [5] and oxidized the surface machined without crack propagation after heat treatment [6].

Use of two-phase medium in ND-EDM improved the *MRR* and eliminated the problem of debris deposition [7]. Moreover, good machining stability and surface finish were also achieved [8]. *TWR* was negligible as compared to wet EDM with all combinations of dielectric mediums. Most commonly used two-phase (liquid-gas) dielectric medium are the kerosene-air [8,9] deionized water-air [10] and air-water [11–13]. Wong et al. [14] suggested the adding of powder in the liquid dielectric medium for higher machining stability with uniform dispersion of discharge at IEG. Gao et al. [15] also suggested that use of three-phase dielectric medium (liquid-gas-solid powder) instead of the liquid dielectric medium improves the field strength at IEG which helps for easy breakdown of dielectric medium and enlarges the plasma channel of discharge. Use of mist of three-phase (EDM oil-air-silicon powder) in PMND-EDM improved the deionization of dielectric medium and

exerted force for removing material [16,17]. It is revealed that literature review on three-phase dielectric medium is still lacking.

In this study, different dielectric mediums such as deionized water (DW) for wet EDM, DW-air for Near Dry-EDM and DW-air-graphite, DW-air-manganese & DW-air-silicon carbide for Powder mixed Near-Dry EDM, are investigated to determine their effect on the machining performance.

NOMENCLATURE

Symbol Abbreviation

<i>MRR</i>	Material removal rate (mm ³ /min)
<i>TWR</i>	Tool wear rate (mm ³ /min)
<i>SR</i>	Surface roughness (μm)
<i>ΔW</i>	Loss of workpiece before and after machining (g)
<i>ΔT</i>	Loss of workpiece before and after machining (g)
ρ_w	Density of workpiece (g/cm ³)
ρ_t	Density of tool (g/cm ³)
<i>t</i>	Machining time (min)

EXPERIMENT SETUP

All the experimentation work was carried out on electrical discharge machine (EDM) manufacture by Savita Machine Tools, India. The EDM is modified with a minimum quality lubrication (MQL) system manufactured by Dropsa for producing the two-phase (liquid-gas) and three-phase (liquid-gas-solid powder) dielectric medium. The schematic working diagram of EDM with two-phase/three-phase dielectric medium is shown in Figure. 1. Combination of deionized water (DW), air, solid powders (graphite (Gr), manganese (Mn) and silicon carbide (SiC) powder) were used for producing the different dielectric mediums such as deionized water (DW), DW-air, DW-air-Gr, DW-air-Mn and DW-air-SiC. An air compressor was used to generate the compressed air and mixed with deionized water at the MQL device and formed two-phase near dry dielectric medium (DW-air), then supplied at the IEG. Likewise, for producing the three-phase dielectric medium of DW-air-solid powder, the fine solid powder (graphite/manganese/silicon, <20 μm) is initially mixed with deionized water (DW-powder) at the MQL reservoir, then mixed with compressed air at the MQL device and supplied to the IEG. Supply of the compressed air to the MQL device is controlled by a solenoid valve which works on a pulsating signal. The experimentation work was carried out on the EN-8 workpiece with a copper electrode.

Weight loss of workpiece and tool is measured by using Cortex (1 mg resolution) method is used to calculate the material removal rate (*MRR*) & tool wear rate (*TWR*) and given in Eqs. (1) & (2) respectively.

$$MRR = \frac{[\Delta W]}{\rho_w t} \times 1000 \text{ mm}^3 / \text{min} \quad (1)$$

$$TWR = \frac{[\Delta T]}{\rho_t t} \times 1000 \text{ mm}^3 / \text{min} \quad (2)$$

Density of EN-8 workpiece is 7.8 g/cm³ and copper tool is 8.9 g/cm³. Each experiment is operated for 25 minutes.

The machining process parameters for the experiment were identified from literature survey and machine capability (Table 1).

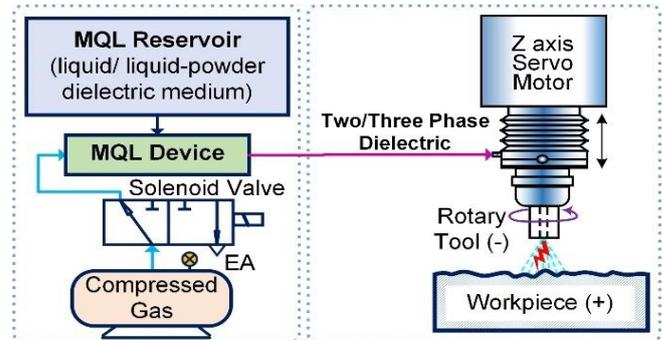


Figure 1: Working diagram of EDM with two-phase/three-phase dielectric medium

Table 1. Machining process parameters for the experiment

Process parameter	Unit	Wet EDM	ND-EDM	PMND-EDM
Dielectric Medium	-	DW	DW-air	DW-air-solid powder
Tool polarity	-	Negative	Negative	Negative
Machining time	min	15	15	15
Discharge current	A	5	5	5
Duty factor	-	0.8	0.8	0.8
Pulse on time	μs	50	50	50
Gap voltage	V	50	50	50
Tool rotational speed	rpm	200	200	200
Powder concentration	g/L	-	-	8
Working Pressure	bar	-	5	5

RESULTS AND DISCUSSION

Comparison of MRR for wet EDM, ND-EDM & PMND-EDM

From the Figure 2, it is observed that use of deionized water in the wet EDM process has higher MRR from the ND-EDM &

PMND-EDM which used the dielectric medium such as deionized water-air and deionized water-air-solid powder respectively. This is due to MRR depends on the dielectric strength and viscosity of the dielectric medium. Dielectric strength and viscosity of deionized water is lower while mixing with the air (low dielectric strength) to form deionized water-air and deionized water-air-solid powder. Breakdown of dielectric medium is depending on its strength, higher the value of dielectric strength leads later breakdown as compared to the lower value of dielectric strength medium. Thus, higher the discharge energy is applied at the electrode gap and the amount of material removal increases.

Moreover, viscosity of the dielectric medium leads to restrict the plasma channel, thus discharge energy is applied at smaller area resulting in more removal of material from the workpiece. However, mixing of solid powder in deionized water-air dielectric medium enlarge the IEG distance that improves the machining stability, thus it diminishes short circuit as in ND-EDM. Therefore, material removal rate is more in PMND-EDM from the ND-EDM. However, deionized water-air-SiC powder dielectric medium produced high explosive force resulting in high MRR from the other three-phase dielectric mediums.

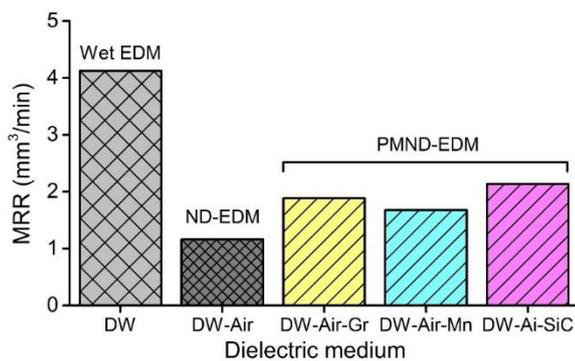


Figure 2: MRR of Wet EDM, ND-EDM & PMND-EDM

Comparison of TWR for wet EDM, ND-EDM & PMND-EDM

From the Figure 3, it is observed that PMND-EDM has less TWR as compared to wet EDM and ND-EDM. Wet EDM that uses higher dielectric strength and viscosity dielectric medium (deionized water) produced higher discharge energy results in higher eroding of tool material. TWR is comparatively low in all the dielectric medium of PMND-EDM that enlarging the IEG which helps to diminish the short circuit. TWR in PMND-EDM and ND-EDM is comparatively low and negligible.

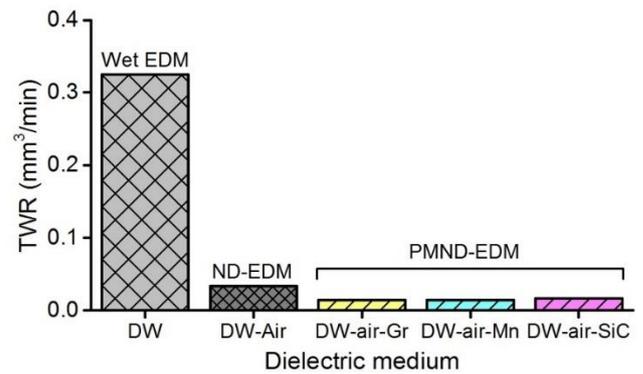


Figure 3: TWR of Wet EDM, ND-EDM & PMND-EDM

Comparison of surface roughness (SR) for wet EDM, ND-EDM & PMND-EDM

From the Figure 4, it is observed that use of three-phase dielectric medium can achieved lower surface roughness as compared to the wet EDM and ND-EDM process. IEG of wet EDM and ND-EDM process is small that causes unidentified short circuit resulting in improper melting and solidification on the workpiece. However, adding of powder enlarged the IEG that diminished the short circuit and helps in stability in machining. For larger IEG, more eroded molten particles can be removed easily that reduces the inclusion of unwanted materials on the machined surface and produced good surface finish. Moreover, dispersion of the electric discharge is wider while adding solid powder in the dielectric medium, thus smaller and swallow carters are formed on the surface of the workpiece resulting in decreasing the surface roughness. Thus, all the three-phase dielectric medium which used graphite, manganese and SiC can improved the surface finish. Whereas, presence of SiC in the deionized water-air dielectric medium generated larger explosive force that produces larger crater sized on the machined surface as compared to the presence of graphite and manganese powder resulting in higher surface roughness among three-phase dielectric medium. Although, use of graphite which has higher lubricity produced lower surface roughness as compared to the other three-phase dielectric medium.

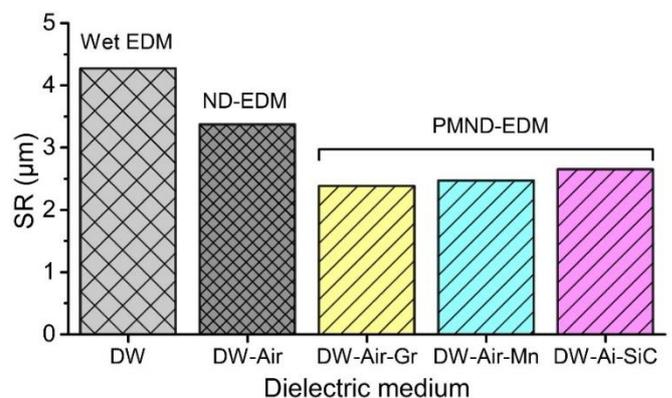


Figure 4: SR of Wet EDM, ND-EDM & PMND-EDM

CONCLUSION

A comparative study on on wet EDM, near dry EDM and powder mixed near dry EDM was carried out by using different dielectric medium such as deionized water for wet EDM, deionized water-air for ND-EDM, deionized water-air-graphite powder, deionized water-air-manganese powder & deionized water-air-silicon carbide (SiC) powder for PMND-EDM. The following results are found and listed below:

- a. Wet EDM has highest MRR, TWR and SR as compared to the ND-EDM and PMND-EDM, thus it can be used for rough machining process.
- b. TWR of the PMND-EDM is quite low and comparatively negligible.
- c. Lower SR machined surface can be achieved while machining by PMND-EDM in most of the powder added dielectric medium. Thus, PMND-EDM can mainly use for surface finishing of EDM process.
- d. Use of graphite powder can give lower surface roughness from manganese and SiC powder.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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