

EFFECT OF DIELECTRIC ON ELECTRICAL DISCHARGE MACHINING: A REVIEW

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Abstract. In the present study a comprehensive work has been carried out to investigate the influence of dielectric on machining parameters of EDM process. An EDM is a non- traditional thermo- erosive process used to machine a materials irrespective of their hardness. It produced a highly précised and better surface topography in materials. Dielectric is an important parameter in EDM and plays a crucial role in determining high material removal rate (MRR) and surface finish during operation. The dielectric fluid behave as a medium which controls the electrical discharge and absorb heat during process. It remove the debris particles and cool the work piece. Adding of powder such as Ti, Si, graphite, Cu, Al₂O₃ etc. in dielectric fluid increases the fluid conductive nature with an increase in micro-hardness of material. Selecting suitable dielectric from different present fluids is highly essential for conducting experiment in EDM. This paper presents the literature views of use of different dielectrics and its effect on optimization of machining parameters and respective characteristic properties.

1. Introduction

An EDM is a non- conventional thermoelectric machining process used to machine a conductive and semi-conductive materials irrespective of their hardness. It's a non- contractive thermal erosive process used to cut high strength and temperature resistant alloys/metals. EDM process is an advanced technology used basically in manufacturing industry for its high precision, high machining rate and better surface finish [1]. With the development of EDM process various variation of EDM techniques were developed like sinking EDM, wire EDM, milling EDM and micro-hole EDM drilling etc. to intricate different operations on materials. In an operation of EDM process, a significant potential difference is developed across (electrode) tool and work piece, resulting in a breakdown of atoms in dielectric medium where atoms are forced to get ionized and create electrical spark enough to melt and vaporize metal from work piece. This high concentration of ions in gap act as electrical bridge between tool and work piece such that region produce is in plasma state with a temperature of 8000K - 12000K. Towards the end of the machining process, the plasma channel collapses leading to deposition of some of these constituents on the machined surface under appropriate process conditions.

Function of dielectric in EDM process:

- The dielectric fluid controls the electrical discharge pulsation.
- Absorb heat during process.
- Compresses the formation of bubbles



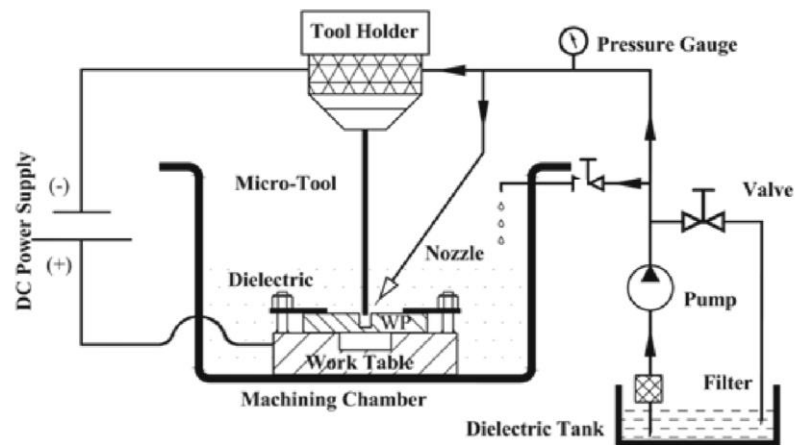


Figure-1 Working of EDM process [27]

- Cools the melted debris and remove (flushing technique) debris particles from electrode – work piece gap.

With an addition of powder like Cu, Al, graphite etc. to a dielectric fluid (PMD) generates low insulating strength i.e. resistivity of dielectric decreases and consequently increasing the inter electrode space resulting in easier removal of debris particle. Conductive powder addition in dielectric fluid produce high MRR and improve the surface finish [1]. Nowadays numerous study and research proved that a dry EDM process can be carried out using gaseous dielectric with small additives in order to have environment friendly and economical machining process [2]. Without compression on discharge generated bubble by liquid dielectric, the material removal can also be take place in case of gaseous dielectrics. The different types of dielectrics being used during EDM process has been described in figure 2. The working of EDM has been depicted in figure 1.

2. Types of Dielectrics:

2.1. Hydrocarbons & biodiesel dielectric oils: It's an old and original based dielectric used for sinking EDM process. Examples- Kerosene oil, diesel. These oils has serious issues of its reuse and non-degradability. Several hazardous fumes, aerosols and toxic gases emitted from these oils during process. But nowadays environment friendly and naturally prepared hydrocarbon dielectric oil is being used like biodiesel oils-Jatropha based dielectric and organic type dielectrics made for biomedical application are-Bioactive hydroxyl apatite suspension type.

2.2. Water & Water based additives dielectric fluid: Both normal and deionized water based dielectric are commercially used for machining in EDM. They are environmental free and cheaply available. But results produced by this fluids are unsatisfied and unfavourable.

Nowadays water in oil emulsion based dielectric is being used to obtain an effective result like glycol in water, machine oil in water, glycerine in water etc.

2.3. Gaseous based dielectric fluid: Use of O_2 and air are common types of dielectrics being used in EDM. These are least hazardous and produces less pollutant compared to other dielectrics being used in process. However with proper arrangement, these dielectrics perform comparable to other dielectrics. Addition of additives like glycerine can enhance gaseous dielectrics.

2.4. Powder mixed dielectric fluid: It's a new technique widely used for machining materials. It provides better surface topography with reduction in surface roughness, cracks and holes. This dielectric comprise of powder of conducting materials like SiC, graphite, Al_2O_3 , Al, Cr and kerosene as a fluid. These dielectric enhance the electrical conductivity with low resistance and allowed large metal removal process.

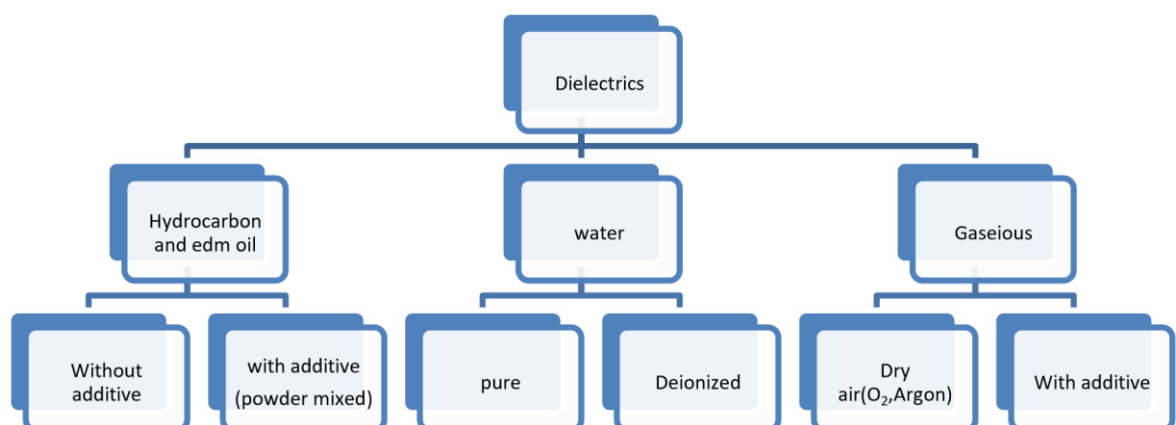


Fig.2-Types of Dielectric used in EDM

3. Effects and Research trend of dielectrics in EDM

3.1. EDM with hydrocarbon/edm oil based dielectric:

Hydrocarbon and edm oil based dielectric are one of the traditional dielectric being used in EDM for machining. They are least volatile and free of ions providing better machinability. They inhibit the process of formation of bubble in process. Janak et al. investigated the technical feasibility of jatropha oil to improve the sustainability of EDM process. The experiment was conducted on M28 HH grade mold steel with copper tool as electrode. Jatropha biodiesel resulted higher MMR, lower SR, higher Surface hardness (SH) and lower tool wear rate compared to kerosene under the influence of variable current, gap voltage pulse on and off time [3]. Misbah et al. conducted work on material Al6061 T6 alloy to study the effect

of kerosene and water dielectric on MRR, SR, electrode wear rate (EWR) and micro-structure. It was found MRR is higher for kerosene than distilled water because of the arcing phenomena which occurred in distilled water. Also, Kerosene showed lower EWR than distilled water because carbon content got stuck to electrode surface which hindered further wearing. High surface roughness was obtained in distilled water in comparison to kerosene [4].

Jagdeep and Rajiv studied the effect of different dielectric on cobalt-bonded tungsten carbide (WC-Co) material. They observed that edm oil produces high MRR rate with increasing pulse current compared to kerosene and water. Also with increase in flushing pressure of dielectric MRR increased. Addition of graphite resulted in lower tool wear rate and electrode wear rate [5]. Shuliang et al. investigated experiment on Be-Cu alloy to study the surface quality of micro-holes using kerosene and water as dielectrics with multi-diameter electrode. The experiment was performed in two stages in the first stage, the front of the multi-diameter electrode and deionized water as dielectric was used and in the second stage, with kerosene as dielectric. The large diameter part of multi-diameter electrode was used to improve the surface quality of the micro-hole. The surface topography of metal using deionized produces high discharge craters and electrochemical corrosion pits where as in kerosene dielectric only craters was observed. The diameter of micro-holes machined using deionized water was larger than using kerosene, which provides a reference for the selection of the diameter of multi diameter electrode [6].

3.2. EDM with hydrocarbon oil with additives:

Addition of conducting powder like chromium, aluminium oxide, graphite etc.in hydrocarbon dielectric increase conductive strength of electrical spark via decreasing fluid resistivity. They enhance the micro hardness and decrease TWR and EWR simultaneously. Different powder additive with variable concentration are described below with their effects on process parameters. Figure 2 depicts the PMEDM process using hydrocarbon oil dielectric.

3.2.1. Silicon Carbide (SiC) powder additive:

S.tripathy and D.k tripathy investigated the effect of process parameters like powder concentration in dielectric, peak current, and pulse on time and gap voltage on MRR, Surface Roughness, Recast Layer Thickness and micro hardness simultaneously during PMEDM of H-11 die steel. They found that without use of powder mixed in oil as dielectric produces poor surface quality, more crack density, holes, pits etc. with non-uniform surface roughness. On addition of SiC (silicon carbide) powder in dielectric, surface topography was improved with less cracks and defects. With the increased in SiC powder concentration, the surface texture showed tremendous improvement with increased in material removal rate, reduced surface roughness, recast layer thickness, improved micro hardness and superior surface quality with less micro-crack. Suspending SiC powder into the dielectric fluid widened the gap compared to earlier EDM processes which facilitates the flushing action and brings stability to the process [7].

3.2.2. Aluminium and graphite powder additive:

Anirban et al. studied the effect of Al and graphite powder to produce optimal surface quality and finishing in EN31, H11 and HC-HCr material using copper as electrode. Adding aluminium in dielectric fluid enhances MRR whereas adding graphite resulted in low MRR but better surface finish. EN31 has greater MMR with Al powder mixed with dielectric fluid (kerosene) compared to H11 and HC-HCr under same operating condition. HC-HCr required higher current and pulse on settings for initiating a machining cut and works best in combination with copper electrode and graphite powder for improved finish [8].Murahari and Adepu

investigated the effect of surfactant and graphite powder as dielectric to analyses the material removal rate, surface roughness, Tool wear rate and recast layer thickness on Ti6Al4V-alloy material. Copper tool as electrode was chosen. The experiment conducted on material Ti-alloy produces favourable result and shows that MRR was increased with increase in graphite concentration and also with increment of surfactant MRR increase up to certain limit. In experiment Recast Layer thickness (RLT) was directly proportional to low discharge current and high graphite concentration. Surface roughness (SR) was decreased with increased in graphite and surfactant (dielectric) concentration [9]. Ajay et al. studied the material transfer effect from powder mixed dielectric into die steel EN31, H11 and HC-HCr material using copper and tungsten as electrode. Graphite powder mixed kerosene dielectric provide optimum result compared to aluminium powder. The studies shows effect of powder concentration in dielectric influencing die steels properties. Micro hardness, surface roughness, cracks and pits were improved using powder in hydrocarbon oils. Also material transfer in die steels enhanced the quality and surface integrity. Copper electrode and graphite with kerosene oil provides suitable result for EN31 and H11 whereas copper-tungsten electrode proved better result for HC-HCr die steel [10].

3.2.3. Chromium powder additive:

Ryota et al. worked on the improvement of surface characteristic of material SKD11 using chromium powder mixed with kerosene oil as dielectric under EDM process. He found that material hardness, corrosion resistance and surface roughness was improved. On comparison with other dielectrics (water, kerosene, pure Cr), Cr powder with kerosene produced optimum result. The Vickers hardness, water repellency and corrosion resistance of EDM finished surface was increased by using chromium powder mixed fluid [11].

3.2.4. Tungsten powder additive:

Sanjeev and Uma studied the effect of surface modification of three different die steels under EDM process using Tungsten powder mixed with kerosene dielectric oil. H13, OHNS die and HC-HCr die steel was used for experiment with tungsten as dielectric powder. Under appropriate machining process tungsten powder transfer occur from dielectric to die steels enhancing micro-hardness and improving surface finish with less craters and pits. Usage of powder mixed dielectric offers high MRR and better surface topography [12].

3.2.5. Aluminium Oxide, Graphite and Silicon Carbide powder additive:

Mahendra et al. investigated the effect of powder mixed dielectric of aluminium oxide, graphite and silicon carbide on material INCONEL 718. They found that MRR increased at 85% of duty cycle on addition of graphite in kerosene oil as dielectric whereas tool wear rate was lowered on addition of silicon carbide [13]. Assarzadeh and Ghoreishi studied the effect of optimization of parameters using Al₂O₃ powder mixed EDM process. Fine abrasive powder of aluminium oxide (Al₂O₃) is mixed with kerosene oil to form dielectric in order to investigate its effect on CK45 material. Produced results depicted that MRR increases, Surface roughness decreased and micro-hardening process of metal gets enhanced compared to simple kerosene as dielectric in experiment and optimal result was carried out using Response surface method [14]. Anirban et al. investigated the surface optimization and powder dielectric migration (S, graphite) on die steels namely h11, HC-HCr and AISI 1045 respectively. Addition of powders in dielectric improved the surface finish via migrating into the machined surface and too improved the micro-hardness. The brass electrode and tungsten powder resulted in good surface finish in H11 and AISI 1045 whereas W-Cu electrode and W powder gave higher micro hardness in HC-HCr [15].

3.2.6. Magnesium and Aluminium powder additive:

Maan and Azzam studied the effect of using powder concentration of magnesium(Mg), Aluminium(Al) and magnesium –Aluminium as dielectric powder on die steel AISID3, AISID6 and H13 using copper electrode to evaluate surface roughness(SR). They found that the addition of manganese powder mixed with dielectric resulted in low SR when compared with aluminium powder and mixed powder aluminium and manganese respectively [16].

3.2.7. Titanium Carbide powder additive:

Velusamy and Bidwai studied the effect of titanium carbide particle addition in the aluminium composite material. They found machining of composites is difficult and high accuracy with perfect surface finish is required. Using kerosene with titanium carbide powder enhance higher MRR with improved surface topography but decrease as TiC content increases MRR was increased with high flushing temperature and craters were reduced[17]. Similar studied was used to the multi response optimization on material EN-19 using Tungsten powder mixed dielectric in order to increase MRR and surface quality. Larger MRR was achieved in powder mixed EDM as compared to conventional EDM with better surface regime [18].

3.2.8. Bioactive Hydroxyapatite powder additive:

Shih-Fu and Cong-Yu studied the effects of bio-ceramic particles i.e. bioactive hydroxyapatite (HA) powder suspension as the dielectric of powder-mixed in electrical discharge machining on titanium and titanium–tantalum alloys material. Using bioactive dielectrics produces non-toxic and bioactive species in materials highly useful for biomedical field of applications. During experiment they found MRR, EWR, surface roughness, and thickness of the recast layer showed a strong initial decrease on addition of HA dielectric but MRR gradually increased after increase in dielectric amount. The recast layers contained higher titanium, tantalum, oxygen, calcium, and phosphorus, and exhibited greater hardness and anti-scratch properties on comparison with pure titanium [19].

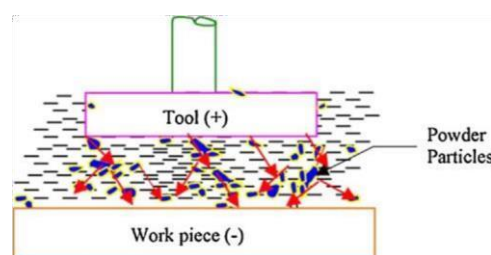


Fig. 3. Principle of powder mixed EDM [2]

3.3. EDM process with gaseous dielectric and with additives:

Gaseous dielectric also called as dry EDM process is an environmental friendly and least hazardous dielectric in comparison to other dielectrics being used in industry. Its high velocity and pressure allows simultaneous work of removing debris particle and as working medium for electrical discharge in process. Also, with addition of glycerine as additive enhance dielectric property. Kao et al applied the near-dry process in wire EDM using water-air mixture and found the benefit of better machining stability and

higher MRR than the wet EDM in finishing process. Using the gas or liquid-gas dielectric medium, the dielectric disposal of dry or near dry EDM is cleaner than that of PMD EDM [20]. Yu et al demonstrated the effectiveness of the dry EDM method for groove milling and three dimension milling in cemented carbide. Copper-tungsten tubes was used as tool electrodes and high velocity oxygen gas as the dielectric. Dry EDM performance was compared to oil die sinking EDM and oil EDM milling. It was found that dry EDM milling produces the smallest form deviation due to very low tool wear ratio. The machining speed in dry EDM was higher than for oil milling EDM but lower than oil die-sinking EDM [21]. Zhang et al [22] studies on ultrasonic-assisted electrical discharge machining using gas dielectric. The material removal rate (MRR) is nearly twice as much as EDM in gas, though is less than that of conventional EDM. They used 45 steel and copper as tool electrode to perform UEDM process. Krishnakant and Akshay worked on near dry EDM process using air and glycerine as dielectric in order to produce eco-friendly machining process compared to conventional EDM. The experiment was conducted on EMS 5030 die using Copper as a tool. Combined effect of process parameters was used to analyse MRR and it was found air-glycerine produce more reliable result i.e. higher MRR compared to water-air dielectric medium. RSM approach was utilized to calculate optimum result [23].

3.4. EDM process with pure water and deionized water:

Water based dielectric in edm process brings high thermal stability with tolerance of high input parameters allowing higher metal removal rate. It has a decent dielectric properties compared to other oil based dielectric. Do Kwan et al studied the use of deionized water instead of kerosene on 304 stainless steel with tungsten carbide as tool and found that the tool wear was reduced with increases in the machining speed. The machining time also decreases because of a fast machining federate [24]. The similar investigation was carried out on Ti6Al4V alloy in water and kerosene based dielectric [25]. They found that carbide layer was generated in kerosene dielectric whereas oxide layer were observed in water dielectric. Also, the debris size in water dielectric was greater than that of kerosene dielectric. ChingTien et al [26] studied the effect of pure water dielectric on micro slit edm process. Experimental results shows high material removal rate (MRR), low electrode wear, small slit expansion, and little machined burr, compared to positive polarity machining was obtained in Ti6Al4V material. In comparison with that of kerosene, pure water was observed to cause low carbon adherence to the electrode surface in copper tool. An experiment conducted over Ti6Al4V using deionized water, kerosene and copper additive in water as dielectrics. They found that MRR was high in case of deionized water than kerosene and with addition of copper in deionized water increases MRR more significantly. The white layer thickness was also minimum in case of deionized water [27].

Y.Zhang et al. investigated the influence of dielectrics on material mild steel 8407. He experimented on 8407 steel as a work piece and steel tool as electrode with De-ionized water, kerosene, water in oil (W/O) emulsion and gaseous (O₂ & air) as dielectrics and found that higher metal removal rate efficiency is in W/O emulsion dielectric followed by kerosene, water and then air. From both experimental and simulation results the higher removal rate is found in W/O emulsion dielectric due to high pressure above discharge point [1].

Conclusion

The conducted experiments and demonstrated results by researchers, proved that dielectric has a great impact while performing operation using electrical discharge machine process. It plays significant role in

machining optimization of different process parameters. The followings are observed function played by dielectrics:

- It works as a medium
- heat absorbent
- conductive fluid
- Reduce EWR and TWR and improve surface topography.
- Effect on increasing MRR and decreasing surface roughness with increases in micro-hardness of material.
- Reduces white layer formation

Therefore, dielectric is influential aspects to be consider during machining of material in EDM process. From above performed EDM process operation powder additives mixed with oil produces optimum result compared to other dielectrics being used. Further more experimental investigation is required to deeply study the effect of dielectric and its non-linear function on work piece in EDM.

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