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A State-of-the-art Review on Dielectric fluid in Electric Discharge Machining: Uses and Its Effects

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Abstract - *Electro Discharge Machining (EDM) is one of the earliest Non-Conventional, most accurate manufacturing processes available in which material removal take place by melting and vaporization. EDM is based on thermo-electric energy in between the electrode and work piece. Dielectric fluid which are used in Electro-Discharge Machining (EDM) plays a very important role in deciding the Productive aspects i.e. Material Removal Rate, Tool wear Rate and the machined part properties. Selecting dielectric fluid in a corrective manner is a crucial decision for obtaining better productive aspects. This paper covers Literature reviews on the uses of dielectric fluid in different EDM research work and also their effects on the Characteristics of EDM.*

Key Words: Unconventional machining, Electro Discharge Machining (EDM), Dielectric fluids, Productive aspects, machining surface roughness

1. INTRODUCTION

K.H. Ho & S.T. Newman (2003) Electro Discharge Machining is a concept of non-conventional, high energy machining having vast application in moulds and die making. The complex shapes and difficult to machine components of Aerospace, Automotive industries and Surgical parts are also manufactured by the EDM process [10]. S. Singh et al. (2004) Development of EDM is done in late 1940s [21]. Luis CJ et al. (2005) In this machining, removal of material was based on series of reiterated electrical discharges happens in between work piece and the electrode without contact in the environment of a fluid which is dielectric in nature [17]. Bojorquez B et al. (2002) The gap between the work piece and the electrode is decrease by electrode movement towards the work piece unless the gap is sufficiently small so that the dielectric ionization is done by the applied voltage [2]. Marafona J & Chousal J.A.G. (2006) Discharge of very short duration is occurred in a gap, which is filled by the liquid dielectric, separates work piece and the tool. Due to erosion effect of work piece and the tool the removal of work piece material take place [19]. Frei C. (1992) The decisive role of dielectric in EDM is given by Boris and Natalie I. Lazarenko in 1940s [6]. The classification of EDM can be done on the basis of Dielectric fluid used. Fluid which is used as dielectric has greater impact on the quality and properties of the machined part. Since the compositions and cooling rates varies from fluid to fluid so the proper selection of dielectric fluid is the crucial decision for better machining. Dielectric fluid circulates in between the work piece and the tool and it is fully responsible for the high performance and the Electrical spark controlling. Fábio NL & Ian RP. (2004) Dielectric cleanliness and consistent gap performance is obtained by the filtration system which is in build in the EDM machine. The basic function of dielectric fluid is a. insulation b. ionization c. cooling d. waste particle removal. Different kind of dielectric fluid is used in EDM such as Hydrocarbons oils, deionized water etc. Generally, Hydrocarbons oils are used in die sinker EDM while deionize water are used in Wire-EDM, micro-EDM [7]. Generally in conventional EDM, Kerosene is used as dielectric fluid that creates lots of problems while machining such as dielectric properties degradation, Air pollution, carbon particle gets deposited on the work piece. Due to all this the stable discharge obstructed results in lower machining rate and efficiency. Since the property of dielectric is the key property in deciding the quality and efficiency of the machined products so the investigation is carried out to search alternative to kerosene dielectric with better dielectric properties eliminating all other drawbacks of using kerosene. The objective of this paper is to present the use of multiple kinds of fluids which is used as dielectric and effects of these fluids on Characteristics of EDM.

2. Research Trends in EDM

The research trends in EDM are mainly classified into four categories as

1. Process Parameters Optimization
   a. Parameters related to Electrical and Non-Electrical
   b. Design of electrode and manufacture
2. Controlling the EDM Process
   a. Pulse/Time domain
   b. Fuzzy logic
   c. Radio frequency
3. Productive measure improvement
   a. Rate of Material Removal (MRR)
   b. Rate of Tool Wear (TWR)

c. Surface Roughness (R_a)
4. EDM Machine and process Development
   a. Application of EDM
   b. Hybrid machining Process

Various researchers show interests in different aspects of EDM. In present study, the main focus is on the fluid used as dielectric in various EDM process, its effect and future improvement in EDM characteristics.

3. Dielectric fluid function

Kern R. (2009) The dielectric fluid serve number of function in Electro discharge machining as: [11]

a. For controlled electric discharge it act as a medium through which it happens smoothly
b. For cooling medium, to cool down the gaseous debris which is obtained by discharge.
c. For flushing medium, used to eliminate EDM debris stuck between the work piece and tool to the filter system.
d. For Transfer of heat medium, to absorb and eliminate the produced Heat by the spark between tool and work piece.

4. Dielectric Fluids and its effects on EDM

4.1 Mineral Oils

Kern R. (2009) Minerals oils are obtained in by products of distillation of petroleum. And they are widely used dielectric oils in conventional EDM process but have some drawbacks like air pollutions, bad odours. So they are avoided recent days [11].

4.2 Kerosene

Kern R. (2009) Due to low viscosity and good flushing quality it is widely used and famous dielectric fluid in old days in EDM. But it has some drawback as well [11].

a. Flash point is low
b. Bad odour
c. Highly volatile
d. Reacted on skin

4.3 Mineral seal

Kern R. (2009) Mineral seal oil is extracted from seal blubber, and it is used lighthouses and lamps due to this fact it is named as mineral seal oil. It is the product obtained by petroleum distillation and has vast industrial applications. The aerospace industries also adopted mineral seal oil as a fluid which is consider as dielectric in EDM in past days. It has found that carcinogenic potentially components, are present in the Mineral seal oil and thus The use of this oil is no more recommended [11].

4.4 Transformer oils

Kern R. (2009) Currently, it has no application in EDM but in older days due to its dielectric properties it is used in EDM. Earlier generation of Transformer oil were compounded with PCBs [11].

4.5 Water based dielectric in EDM

Abbas N et al. (2007) Last 26 years water and water with some organic additives is used as an alternative to hydrocarbons oils [1]. Zhang QH et al. (2005) Lots of studies and researches are carried out to promote a better health and healthy environment because hydrocarbons causes Air pollutions (CO and CH_4) while using them in EDM [29]. Abbas N et al. (2007) The water can be used as dielectric fluid in two ways firstly as a pure and secondly after adding some additives in it to enhance its properties for EDM [1].

4.5.1 Pure water as a Dielectric in EDM

Lin YC et al. (2007) The first research on pure water as dielectric in EDM was carried out in 1981 by the jeswani. He compares the distilled water and kerosene performance in EDM in the condition of high pulse energy range 72-288 mJ and it is found that the high MRR and low wear ratio obtained in distilled water than kerosene while in distilled water accuracy of machined part is low but surface finish is higher as comparison to in kerosene [18]. Kruth et al. (1995) investigate the white layer thickness and found that the use of hydrocarbon oil increase the content of carbon on the white layer thickness of the machined surface and appear as iron carbides in columnar, dendritic structures while the use of distilled water eliminates the carbon content as decarbonisation happens[12]. Tariq Jilaniand Pandey (1984) investigate the effect of different type of water in EDM as they uses distilled water, tap water and a mixture of 25% tap water and 75% distilled water and found that the tap water gives the best machining rate [22]. Konig and Siebers (1987) investigate the effect of working fluid on material removal rate. In their study it is concluded that the working fluid has sustained effect on removal process and in water based medium much higher power input and thermal stability is achieved at critical condition results in better removal rate [13]. Chen et al. (1999) conclude that the carbides is formed on the surface of the work piece when kerosene is used in EDM while when water is used oxides is obtained on the surface of the work piece. And the debris size of Ti-6Al-4V in distilled water is found to be greater as comparison to kerosene, better stability and lower impulsive force is obtained in distilled water as comparison to kerosene [4]. Plastic mould steel surface integrity is investigated by Ekmekci et al. (2005) and they found that the austenite amount and intensity of crack is less in white layer in work piece machined in deionized water [5].

4.5.2 Water with additives as a dielectric in EDM

Koening and joerres (1987) compare highly concentrated aqueous glycerine solution with hydrocarbons dielectrics and found in a condition of high pulse duty factor, long pulse duration and high current that glycerine gives better result in productive aspects [14]. Leao and Pashby (2004) investigates the research of some researchers and found that the performance of the demonized water is increased by adding organic compound such as polyethylene glycol 600, polyethylene glycol 400, polyethylene glycol 200, ethylene glycol, sucrose and dextrose [7]. Yan B H et al. (2005) concluded that to obtain the good wear resistance of the machined surface after EDM, Urea solution in water is used as dielectric fluid as the decomposition of Nitrogen take place from the dielectric and it transfer to the work piece so that a compound of TiN in Titanium work piece is formed which resulting in harder layer for good wear resistance properties of the surface obtained by machining [24].

4.6 Gaseous dielectrics in EDM

Gas can be used in discharge machining. Kunieda M & Yoshida M. (1997) A gas flow of high pressure transferred through electrode of a thin walled pipe then the work piece which is in molten form can be removed and easily flushing can be done from working gap without being re-attached to the electrode surfaces. The wear ratio of electrode is almost zero that is the biggest advantages of using gases for different pulse duration. Hence a complex 3D structure can be formed very accurately when it is operated by NC [15]. Using high jet gas increases the evaporated and molten work piece removal and due to this the rapidly expanding bubble of vapour from a dielectric liquid is formed. It also serves the purpose of cooling, removal metal solidification and preventing them to reattach with the surface of the work piece and tool electrode. The other function of gas jet is heat transfer from the discharge done in previous spark and it cool down the temperature of the work piece and tool electrode spot thus it recover the dielectric strength of the gap [15]. While machining with the gas there is no concern is needed for the generation of hazardous gas and water from the dielectric liquid. In this machining the size of machine can be reduced i.e.it should be compacted and the direction of the machining can be arbitrary selected without consideration of gravitation direction as it is unnecessary to use tub of dielectric fluid [15].

Under some special condition viz. tubular electrode with thickness less than 0.3 mm, negative polarity on electrode, electrode should be rotated and high speed gas flow, it is observed that the performance obtained by gas i.e. oxygen and air mixture, is higher than a liquid dielectric [15]. Leao and Pashby (2004) The removal rate of material is higher when we use oxygen as comparison to when air and EDM oil used. Low wear rate is the best advantage of using gas in EDM and it is independent of pulse duration [7]. Zhang QH et al. (2002) The removal of material rate is improved when the ultrasonic vibration is provided to the work piece because it flushes the molten metal which is formed on craters [30].

4.7 Powder additives dielectric fluids

Zhao et al. (2005) When powder is added in dielectric then it became Hybrid material removal process, different from conventional EDM, commonly known as Powder mixed EDM (PMEDM) and it is widely used in EDM finish machining with low surface roughness. In this process abrasive particle of very fine size is mixed with EDM, works on low pulse energy and gives significant result [31].

Zhao et al. (2002) investigate surface Roughness and efficiency of rough PMEDM by using Aluminium of size 10 mm and 40 g/l and they found that the efficiency of machining is increased from 2.06 to 3.4 mm^3/min. When proper discharge parameters are selected then the efficiency of machining can be improved highly with low surface roughness or high surface finish as comparing to traditional EDM [32]. Pecas & Henriques (2003) The insulating strength of dielectric fluid is reduced by electrically conductive powder which increases the gap of spark between the work piece and the tool which results in EDM stability, machining efficiency improves, MRR increases with better surface quality. Lots of research is carried out on surface finish in PMEDM because mirror surface finish is obtained which is a tough task in traditional EDM. The dielectric performance is affected by the size, type and concentration of powder which is mixed in EDM oil [20]. Yan Ming Q & You He L. (1995) The powder of conductive in nature and lipophilic surface agent when used in EDM oil it results in better surface finish and tendency of crack in middle [25]. Yan and chan (1993) analyse the effect of electrically conductive powder in dielectric fluid and found that powder of Aluminium which is electrically conductive enlarge the spark gap and improve dispersion of energy, surface roughness and rate of material removal [26]. Tzeng & Lee (2001) The highest MRR is obtained when chromium is used of grained size 70-80 nm [23]. Jeswani (1981) Investigate the addition of fine powder of graphite of about 4g/l in Kerosene and found that removal rate of material is increased by 60% and also tool wear increased by 15% [9]. Kensal et al. (2005) examined PMEDM in rough machining phase by using Taguchi method they concluded the optimum process conditions with graphite powder, They also concluded that the graphite powder in dielectric fluid effects MRR, tool wear and surface wear in good manner [16]. Yan et al. (2001) worked on SKD-61 steel in PMEDM and concluded that corrosion resistance and hardness of surface of work piece were improved when suitable powder is added in dielectric of PMEDM [27]. Zhao et al. (2002) uses different powder in dielectric with different type of work piece and concluded that the correct combination of work piece and powder is selected to

obtained desirable properties in the machined work piece. By understanding the fundamental mechanism involved in such combinations, it will promote PMEDM to get better properties. [32]

Pecas and Henriques (2003) uses 2g/l silicon in dielectric fluid and obtained smoothly and craters of highly reflective in nature with average roughness of surface [20]. Furutani et al. (2001) conclude the lubrication deposition method while finishing EDM for production of parts which is used in environment of ultrahigh vacuum. In a mixture of molybdenum disulphide (MoS_2) and dielectric fluid, Aluminium is added for smoother surface finish and smaller coefficient of friction than that with the traditional working dielectric oil [8]. Yih-fong and Fu-Chen (2005) analyse the impact of using Aluminium Al, Copper Cu, Chromium Cr and Silicon Carbide SiC powders on the quality of surface of the work piece SKD-11 (die steel) and found that Aluminium gives the best surface quality and smallest particle giver best result [28].

4.8 Dielectric fluid which has low Viscosity

Bradford, J.W. (2008). The fluid which has low viscosity can improve the performance of the Electro discharge machining. The performance of µ-EDM are analyse by applying dielectric of low viscosity then to quantify he prepared the setup to find the Characteristics of dielectric flow and impact on time of machining cycle. In this test, a flushing device of high pressure is used to force the fluid through a pipe electrode and find out the time taken by the fluid to properly fill a tube up to a defined volume. Longer time is taken by the high viscous fluid than low viscous fluid to fill the given volume of tube confirming difference in the flow rate. The test investigate that choosing the low viscous dielectric fluid can greatly improve µ-EDM process as low viscosity fluid provides proper flushing of debris. Low viscosity fluid gives better result where electrodes are smaller in size, more friable and thus more sensitive to hydraulic deflection [3]

5. Conclusion

Lots of work has been reported on Electro Discharge Machining and its aspects. EDM is widely used in industries to do machining of "difficult to machine" material and for obtaining complex geometry. In the present work review has been done on researches done so far in EDM in terms of variety of alternative fluid which is dielectric in nature and their influences on EDM performance. Currently the use of hydrocarbon oils in EDM is on peak but the use of other dielectric fluid such as water, water with additives like glycol, powder additives dielectric gives better performance than hydrocarbons oil. When distilled water is used higher MRR, good surface finish and Low wear ratio but less accuracy is reported under high pulse energy condition. For higher removal rate tap water is preferred. When copper is used as tool and water as dielectric then there is no wear on tool or we can say zero wear rates obtained.

Researches have been carried out to increase performance of EDM by making different dielectric mixture by adding some organic compound in deionized water such as polyethylene glycol 600, polyethylene glycol 400, polyethylene glycol 200, ethylene glycol, sucrose and dextrose. It has been found that MRR is better in this dielectric mixture than hydrocarbon dielectric oil.

When conductive material powder is added to reduce the dielectric strength of the fluid in PMEDM then it is found that stability, machining rate, surface finish increases. Proper selection of powder for different work piece material is the important factor for obtaining desirable qualities of machined product.

Gaseous dielectric air and oxygen can be used in EDM and it is investigated that it gives better machining rate than hydrocarbon dielectric oils.

The low viscous dielectric fluid can greatly improve µ-EDM process as low viscosity fluid provides proper flushing of debris. Low viscosity fluid gives better result where electrodes are smaller in size, more friable and thus more sensitive to hydraulic deflection.

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