Volume 5, Special Issue, June 2018 ISSN: 2348-8565 (Online)
International Journal of Modern Engineering and Research Technology
Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

National Conference on
Advances in Mechanical Engineering and Nanotechnology (AMENT2018)
29-30 June, 2018
Organized by
Department of Mechanical Engineering, University College of Engineering (A),
Osmania University, Hyderabad, TS, India

Study of Vegetable Oil and their Properties for as an Alternative Source to Mineral Oil-Based Dielectric Fluid in Electric Discharge Machining

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Abstract

In Electric Discharge Machining Process (EDM), dielectric fluid and its properties play an important role in material removal mechanism and it leads some environmental issues. Now a day's vegetable oils are tried as dielectric fluid for improvement of sustainability in EDM process. In this work, the various dielectric properties of vegetable oil such as electro chemical properties and electro physical properties of vegetable oil are determined for finding of suitability of dielectric properties as an alternative to mineral oils. Four vegetable oil are considered namely sunflower oil, canola oil, Jatropha oil and cotton seed oil for the estimation of electro chemical properties (dielectric strength) and electro physical properties (Flash point, Fire point, Pour point, Viscosity and specific gravity). These results are compared with commercially used dielectric namely kerosene. The mentioned properties are measured by suitable equipment and also some trial experiments conducted using Electric Discharge Machining. The results are showed that above mentioned vegetable oils have equivalent properties of dielectric fluid and also equal machining performance.

Keywords:— *EDM, Vegetable oil, Dielectric properties*

1. Introduction

Electric discharge machining (EDM) is the most widely practiced non-conventional material removal process used for the manufacture of molds, dies, punches, cutting tools and surface texturing of steel rolls. Current EDM processes utilize hydrocarbon or synthetic-based dielectric fluids. These dielectric fluids have proven their worth through the test of time. The perseverance and the competency of the EDM process, depends upon the use of liquid dielectric. The liquid dielectric provides a cooling medium in discharge gap as well as flushing of debris from the machining zone thereby plays significant roles during material removal mechanism However; they are not environmentally friendly and sustainable. Hydrocarbon and synthetic-based dielectric produce harmful solid, liquid, and gaseous byproducts. The solid and liquid waste proves to be a challenge during disposal as they are harmful to the environment and the flora and fauna. The toxic gaseous byproducts also cause health issues with regard to the operator. Steps should be taken to ensure the sustainability of the EDM process so as to have a cleaner and greener environment required in green manufacturing. The use of vegetable based dielectric in EDM solve the above problems in EDM and also leads the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers. Vegetable oils biodegrade quickly and completely, and also exhibit very low or no toxicity as compared to mineral oils which uses dielectric in EDM process is an eco friendly and environment free machining [1 -3].

During the process, dielectric media undergo dielectric ionization followed by decomposition. It results in emission of solid metallic particles, finely mixed tiny droplets of liquid dielectric and emitted gases in the form of aerosols, toxic gases, and waste dielectric and so on. These byproducts are hazardous to the operator and the environment. The dielectric fluid plays extremely important functions regarding productivity, cost and quality of the machined parts. Functions performed by dielectric fluids in EDM process are grouped into primary and secondary functions as listed below [4].

Primary functions

- To insulate sparking gap between the electrode and workpiece up to breakdown voltage and then break down by ionization for a plasma channel generation;
- To flush away eroded particles (debris) produced in the sparking gap during machining;
- To restrict spark energy into narrow region for higher energy density;
- To re-establish the insulation condition in the sparking gap between the electrode and workpiece
- by deionization when energy level goes below the dielectric breakdown voltage;
- To cool electrode and workpiece materials heated up by the discharge machining.

Secondary functions

- To capture emission products generated because of decomposition of dielectric fluid and vaporized matters of tool and work materials;
- To serve as a liquid absorbing filter for gas and liquid phases when expelled from the gap;
- To minimize electromagnetic radiation effect by immersion of the plasma channel;

- To assist molten metal globules to detach from the workpiece surface;
- To generate an environment for the subsequent discharges to take place uniformly across the sparking gap by minimizing the effect of magnetic field generated by previous sparks.

II. Literature Review

Amanullah et al. [5] were analyzed the electro-chemical characteristics of vegetable oils to find out substitute to mineral oil-based dielectric fluid. the various chemical properties such as break down voltage test, dissipation factor test, acidity number, interfacial tension on mineral oil, canola oil, sunflower oil, olive oil, grape seed oil, peanuts oil. They concluded that considered vegetables could be used as dielectric fluid as an alternative for mineral based oils. Amanullah et al. [6] were analyzed the physical characteristics of vegetable oils as an alternative to mineral oil-based dielectric fluid. the various physical properties such as flash point, fire point, pour point, specific gravity, viscosity, moisture content on mineral oil, canola oil, sunflower oil, olive oil, grape seed oil, peanuts oil. They concluded that considered vegetables could be used as dielectric fluid as an alternative for mineral based oils. Abdullahi et al. [7] were tested the potentials of palm oil as a dielectric fluid. Petroleum and mineral based fluids have some drawbacks such as low flash point, fire point and have low dielectric breakdown voltage, and also not biodegradable and spillage takes long time to decompose. For these reasons Vegetable oils are the alternative source for mineral based dielectric fluids. They were tested the properties of palm oil in comparison with mineral oil such as turbidity, Dielectric breakdown voltage, fire point, plash point, smoke point, relative density, viscosity, thermal conductivity, thermal diffusivity and moisture content percentage. They concluded that the considered oil had a very good potentiality to use as dielectric fluid. Amanullah et al. [8] were analyzed about evaluation of several techniques and additives to de-moisturize vegetable oils and bench mark the moisture content level of vegetable oil-based dielectric fluids. They have noticed that mineral based dielectric fluids are not friendly to the environment where as vegetable oils friendly to the environment. The drawback of vegetable oils is high moisture content. High moisture content is not suitable for power and distribution transformers. The reduction of moisture content in vegetable oils to an acceptable level and safe working level is one of the major developments of vegetable based dielectric fluids. Martin et al [9] were analyzed the suitability of vegetable oil as dielectrics for use in large power transformers. Oil breakdown voltage is a function of absolute moisture and relative humidity. The quality of the oil directly affects the condition of the cellulose insulation as both moisture and acid content affect the rate of cellulose degradation. It has been proposed that natural esters can extend the remaining life of a transformer by protecting the cellulose insulation. It is hypothesized that natural esters reduce the rate of cellulose ageing by removing water from the cellulose and the benignity of the compounds created during oil ageing. The results shows in this paper based on the evidence found that esters are suitable replacements for mineral oil large power transformers. Rajurkar et al. [10] reviewed about sustainability enhancement in nontraditional machining process. They have pointed about importance and various properties of dielectric fluids.

III. DIELECTRIC PROPERTIES

Vegetable oils can be classified into edible, non edible oil and waste vegetable oils. Edible oils are sunflower, canola, cotton seed oil and non edible oils such as Jatropha oil. Vegetable oils should dielectric properties for generate spark to erode work piece materials. Electro physical properties such as flash point, fire point, pour point, kinematic viscosity, thermal conductivity and specific heat and electro chemical properties such as breakdown voltage, dielectric constant, dielectric dissipation factor, interfacial tension, water content, acidity value and dissolved gas analysis of dielectric fluids influence ionization and deionization, plasma channel generation and emission products of EDM process. Some of dielectric properties (flash point, fire point, viscosity and dielectric strength) are tested using following equipments (Figure 1-4).

Figure 1: Flash point tester

Figure 2: Fire point tester

Figure 3: Viscosity tester

Figure 4: Dielectric strength tester

IV. EDM PROCESS

In this work, some trial experiments are conducted with P20 steel as work piece materials and copper, brass and tungsten copper are electrodes materials. Dielectric fluids used are kerosene, sunflower oil, canola oil and Jatropha oil (Figure. 6-9).

Figure 5. Electric Discharge Machine

Figure 6. P20 Steel Sample with Kerosene as Dielectric

Figure 8 P20 Steel Sample with Canola Oil as Dielectric

Figure 7. P20 steel sample with sunflower oil as dielectric

Figure 9 P20 Steel Sample with Jatropha oil as Dielectric

Table 1: Dielectric Properties Value

Sl.No	Properties	Kerosene	Sunflower	Canola	Jatropha	References
1	Viscosity (At 40º C)	1.2199	5.2	4.3-5.83	6.5836	By experiment
2	Density (gm/ml)	0.802	0.879	0.920	0.870	By experiment
3	Flash point (0C)	47	330	330	240	By experiment
4	Fire point (0C)	52	355	350	270	By experiment
5	Dielectric constant	4.7	3.0	3.2	2.53	By experiment
6	Thermal Conductivity (W/mK)	0.15	0.152	0.168	0.157	By reference
7	Specific heat (kJ/kg K)	2.01	1.833	1.910	1.90	By Reference
8	BD Voltage (KV/2.5,mm)	18	60	50	35.8	By reference

V. Results and Discussion

Vegetable oils and their properties influenced EDM process output parameters such as MRR, EWR, RWR, SR and SH. MRR is termed as machining time per unit volume of material removed, which is related to production cost. Higher MRR is desirable for achieving more economical production. EWR is related to the amount of erosion, electrode material experience during the experiment. It is associated with the tooling cost of the process. Hence, lower EWR is desirable to justify the economic feasibility of the suggested bio dielectrics. Relative wear ratio is related to relative material erosion rate of MRR and EWR. Lower RWR is preferable for machining economics point of view. SR is associated with an average roughness of the surfaces produced in EDM. Lower SR is desirable from the accuracy and tribological point of view to maintain a lubricating layer for a longer period and hence longer service life. Higher SH is desirable for improved wear resistance of the surfaces to have enhanced the life of dies, punches and tooling's.

MRR can be increased by higher spark energy density induced due to higher breakdown voltage at higher current level. Improved melting and evaporation of work piece material are observed due to higher oxygen content because of higher average temperature of plasma channel. This higher

Table 2: Dielectric Properties and Their Importance

Sl.No	Dielectric fluid properties	Importance	Vegetable oils	Mineral oils
1	High breakdown voltage	For minimum arcing (random and uncontrolled low energy arc, higher energy utilization ratio)	Higher	Lower
2	Low relative permittivity/dielectric constant	For min. Energy loss, For lower electrostatic energy to minimize magnetic field effect, prevent localized spark reoccurring	Higher	Lower
3	Low dissipation factor	For minimum power loss, prevent aging and deterioration	Higher	Lower
4	Sulphur, iodine and acid numbers	For better personnel health	Lower	Higher
5	Interfacial tension	Easy deterioration of dielectric fluid	Higher	Lower
6	Viscosity	For better cooling capacity	Higher	Lower
7	Flash point	For fire prevention	Higher	Lower
8	Fire point	For fire prevention	Higher	Lower
9	pour point	For better flow characteristic at low temp	Higher	Lower
10	Oxidative stability	For longer working life of fluid	Higher	Lower
11	Oxygen content	For minimum combustion hazard release	Lower	Higher
12	Biodegradability	For environment protection	Higher	Lower
13	Thermal conductivity	For better cooling of electrode and work material and material integrity	Higher	Lower
14	Specific heat		Higher	Lower
15	Density	For better flushing effect	Higher	Lower

oxygen content could have ensured better dispersion of discharge energy to increase MRR. Higher thermal conductivities of vegetable oils than kerosene could have ensured better transfer of thermal energy towards the sparking area. Also, lower specific heat of vegetable oil improves heat utilization ratio, sustain ionized state for longer duration and longer erosion cycles and higher viscosity enhanced debris evacuation tendency to increase MRR. Higher EWR produced by highly conductive discharge channel, number of ions to strike on the electrode surface because of intense oxidation induced due to higher oxygen content of vegetable oils. At higher breakdown voltage produces delayed dielectric breakdown and concentrated spark energy of higher viscosity leads higher EWR. Increased erosion of electrode volume is observed at high viscosity level which delays heat transfer towards work piece to accumulate than electrode. RWR is related to relative material erosion rate of MRR and EWR. Already mentioned that high EWR due to high oxygen content, high breakdown voltage and high viscosity. These properties could have transferred more energy towards work material to erode more work piece material than electrode material. Hence, high value o f RWR is reported. Lower SR values are observed at higher thermal conductivity and lower specific heat which is due to minimized the energy density due to better heat transfer to the surrounding dielectric media to produce shallower craters. Higher SH values are obtained by increased melting and evaporation of higher oxygen content, quenching process due to higher thermal conductivity, better heat utilization due to lower specific heat and minimum solidification due to high viscosity. Table 1 shows the various dielectric properties and their importance [1-10].

IV. CONCLUSIONS

In any manufacturing practice, environmental impact, personal health and operator safety are the important concern. This work is imposed about the sustainability in EDM process through vegetable oil as dielectric in EDM process.

Dielectric fluid and their important functions are given. It has similar properties compared with conventional dielectric and it is possible to replace as dielectric fluid.

Some of the electro physical and electro chemical properties of dielectric fluid properties are experimentally investigated and their values are reported.

Vegetable oils do not contain any harmful organics due to this the degradability is significantly increased.

Results are observed those vegetable oils as dielectric provides equal or more performance than conventional dielectric. It is providing clean, safe and environmental free machining environment.

ACKNOWLEDGEMENTS

The authors would like to thank IEI R &D cell for supporting and funding this research work. Ref.: RDPG2017006.

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