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Analysis of Electrohydrodynamic Flow Phenomenon of Positive Corona Discharge on New and Used Lubricant Surfaces

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Abstract:- Analysis of Electrohydrodynamic (EHD) Flow Phenomenon through deformation on the surface of new and used lubricating oil has been carried out. Positive corona plasma discharge was generated using a reactor with a point to plane electrode configuration. Voltage (V) is increased from 0 kV until arc discharge. The applied voltage interval is 0.2 kV. The distance between the electrodes (d) was varied from 4 mm to 14 mm with an interval of 2 mm. The results showed that the largest current of 43 µA was obtained at the characterization carried out at a distance between the electrodes of 14 mm without a sample, while the smallest current 0,5 µA was obtained at the distance between the electrodes of 4 mm in the presence of a new lubricant sample. The ion wind direction is influenced by the applied voltage and the distance between the electrodes. The value of the ion wind angle decreases with increasing distance between the electrodes, and the ion wind angle increases with increasing voltage. The value of the ionic wind angle in the presence of used lubricating oil samples is greater than that of new lubricating oil. The radius of deformation of the lubricant by the ion wind is affected by the applied voltage and the distance between the electrodes. The radius increases with increasing distance between the electrodes. The radius of deformation in used lubricating oil is greater than in new lubricating oil. Termination of applied voltage, circle deformation will close. The closing of the circle deformation in new lubricating oil is faster than used lubricating oil.

Keywords:- *EHD flow, lubricant oil, circle deformation, point to plane, positive corona*

I. INTRODUCTION

EHD flow is yielded of positive corona discharges are an area that has attracted the attention of many researchers [1,2,3,4]. The EHD flow field can be applied to the industrial sector for the manufacture of pumps and fans without the need for any movers such as pushers, blows or valves, but the movement is caused by the movement the positive ion that follow the direction of the electric field. That is formed so that the air between the electrodes also moves [2,5].

Research that supports the EHD flow theory using gas discharges has been carried out by several researchers. These studies include the analysis of the EHD flow phenomenon on the silicon oil surface using a corona discharge plasma with a positive polarity point-plane configuration electrode [2] and an analysis of the EHD flow direction angle on a positive corona discharge with the configuration the point-plane electrode [5,6]. Recently, EHD streams have been applied as bulk air blowers driven by ionic winds or EHD pumps [7,8]. The most popular are EHD pumps which use sliding discharge [9] and needle-ring-metal pumps [10]. A very promising prospect is that EHD flow has been utilized to accelerate drying, because the process requires a small pressure difference and relatively low heat energy. This has become a very economical option, and has recently begun to be considered for use in the pharmaceutical industry [11.12].

The purpose of this study is to compare the effect of EHD flow on the surface of new and used lubricating oil. In addition, a physical analysis of the EHD flow phenomenon was also carried out. It is hoped that this research can be useful and be able to complete the study and analysis of the EHD flow phenomenon by using a positive corona discharge plasma generator system with a point-plane configuration.

II. RESEARCH METHODS

In this study a positive corona discharge generator using a plasma reactor with a point-plane configuration [5]. The point electrode is made of stainless steel with a diameter of 0.21 mm, while the circular plane electrode made of metal with a diameter of 61 mm. Lubricating oil having a viscosity of 20–50 W is poured onto the surface of the plane electrode. Lubricating oil used as much as 50 drops. The distance between the electrodes (d) is from 4 mm to 14 mm with an interval of 2 mm. Analysis of EHD flow phenomena was carried out by measuring current, deformation radius, and time of the lubricating union with respect to variations in the distance between the electrodes. The schematic of the research circuit is shown in Figure 1. The positive probe from the DC high voltage source is connected to the point electrode which is then connected in parallel with the high voltage probe [5]. The output of the high-voltage probe will be connected to the oscilloscope and ground.

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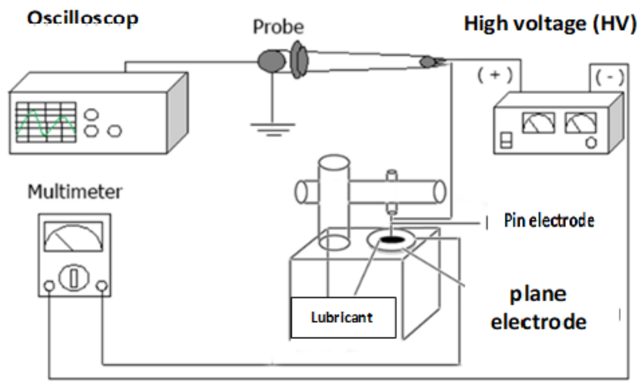


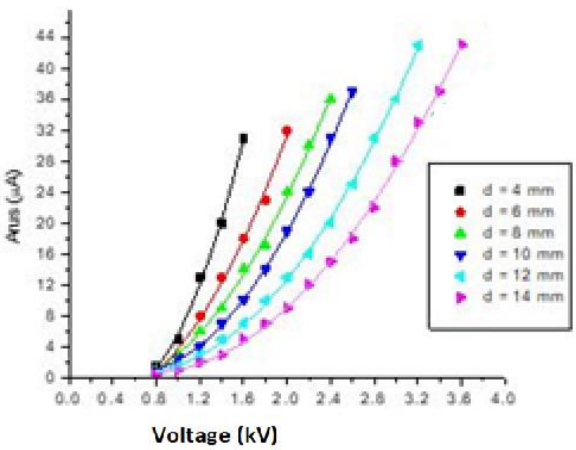
Fig 1:- Schematic of the research circuit

For the negative probe a DC high voltage source is connected to the multimeter and connected to the plane electrode. Plasma generated by high voltage DC with max 10 kV. HV DC was measured by using an Oscilloscope after passing high voltage probe, HV Probe (max DC Voltage DC 40 kV, 28 kV AC EC code number 1010, EnG1010, Made in Taiwan). Electrical signals from the probe detected by an Oscilloscope GOS-653, 50 MHz. The electric current, that was generated in the reactor was measured by using a multimeter (Sunwa TRXn 360) and ammeters (Kyoritsu, AC / DC Digital Clamp meter).

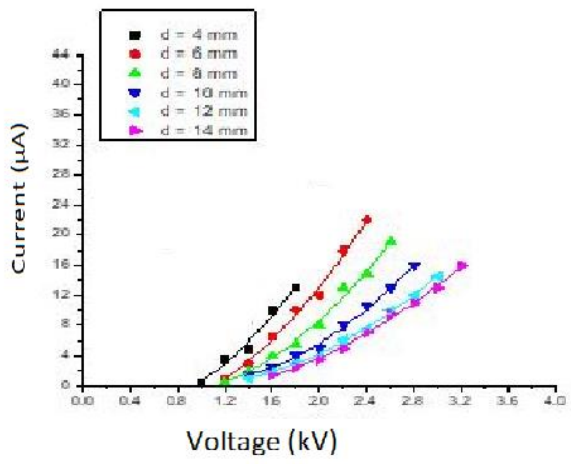
III. RESULT AND DISCUSION

A. Current Characteristics as a Function of Voltage

Current characteristics as a function of voltage in the form of I-V characterization were carried out with a fixed geometry factor [2,6], without the presence of lubricating oil, the presence of used lubricating oil and the presence of new lubricating oil. The graph of the current relationship as a function of voltage is shown in figure 2.



(a)



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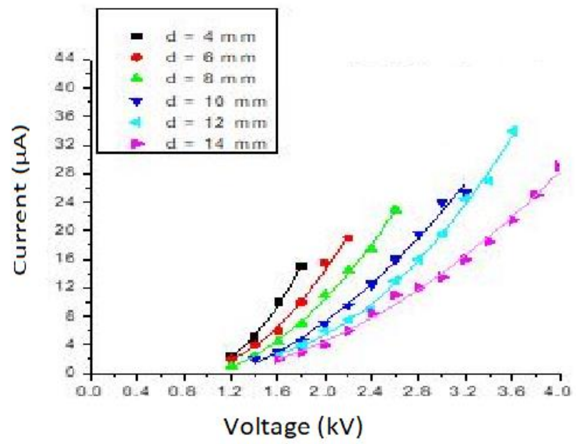

(C)

Fig 2:- (a) Without samples (b) used lubricating oil (c) new lubricating oil. Current characteristics as a function of voltage

Figures 2 (a), (b), and (c) show the current characteristics as a function of the voltage of the plane point positive corona discharge. In the Figure, it can be seen that theg current is a quadratic function (second order polynomial) of the voltage, this is in accordance with the research conducted by Sigmond in 1982 which stated that the current-to-voltage characteristics follow the second-order polynomial equation for corona discharge under atmospheric conditions. It can also be shown that the current as a function of voltage follow law quadratic corona discharge, with a current value proportional to the square of the voltage ($I \approx V^2$)[13]. The same trend was also obtained in the study of very high pressure argon gas, which was obtained with a current value proportional to the square of the voltage [14]. The numerically calculated corona onset voltage is 4.625 kV, and the corona current rises approximately as a square function of the applied voltage above the onset level. In this calculation The *I–V* characteristics for R=100 μm and D =1cm is shown in the same trend [15].

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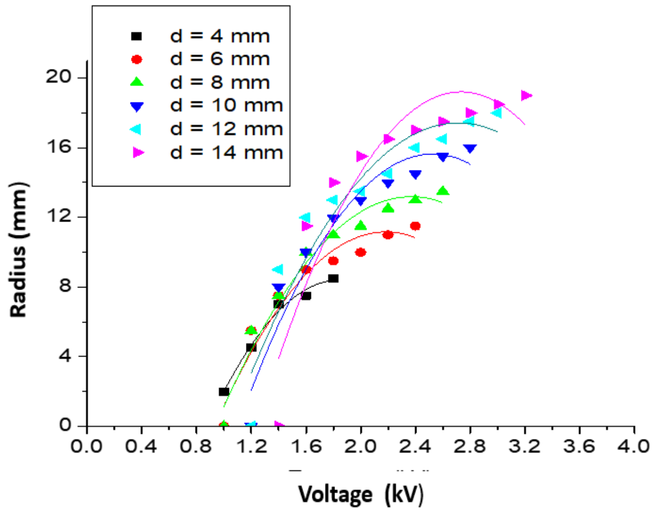
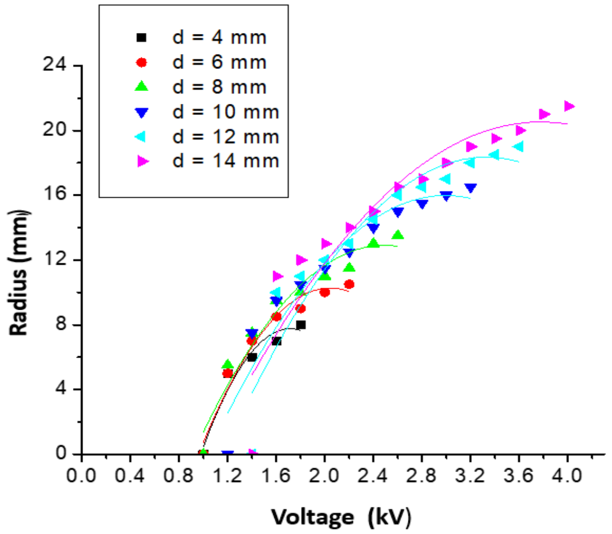
From the three graphs, it can be seen that without a sample the current is the largest compared to used lubricating oil and new lubricating oil. This is due to the addition of a liquid at the plane electrode so that the incoming current will decrease.

B. The Relationship Between sweep radius of EHD flow and Voltage

Figure 3 shows the deformation radius of lubricating oil due to ion wind sweep or EHD as a function of voltage. The deformation is in the form of a circle. The radius of the deformation circle is greatly influenced by the distance between the electrodes and the applied voltage. Figure 3 shows that as the value of the applied voltage increases, the value of the deformation radius of the EHD flow also increases. When the voltage is increased the electric field conditions become higher.



(a)



(b)

Fig 3:- (a) Used lubricating oil (b) new lubricating oil. The deformation's radius of lubricant oil in EHD phenomenon as function of applied voltage

The high electric field will form an electric dipole in the lubricating oil. The radius of deformation of the lubricant oil will be larger. From the two graphs it can be seen that the radius of used lubricating oil is larger than that of new lubricating oil, this is due to the viscosity of the lubricating oil [2]. New lubricating oil is thicker than used lubricating oil, the used lubricating oil will decrease in viscosity. Figure 4 show the radius of circle deformation of used and new lubricant oil as function of applied voltage.

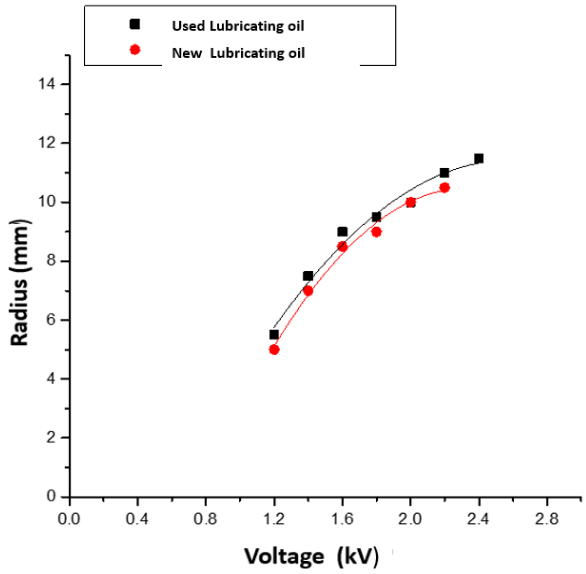
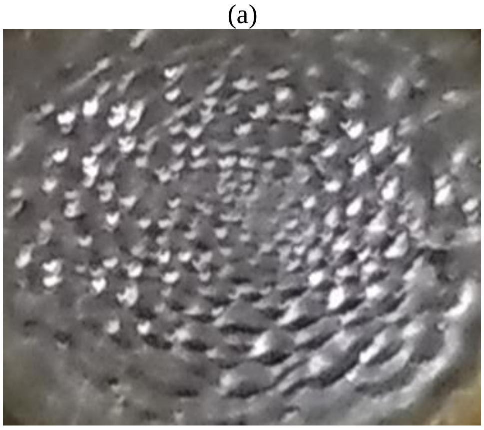


Fig 4:- Radius of circle deformation of used and new lubricant oil as fuction of applied voltage

C. Analysis of the Occurrence of Electrohydrodynamic Phenomena

The process experienced by the surface of the lubricating oil after being subjected to an electric field with high intensity begins with the occurrence of polarization on the surface of the lubricating oil. Ionic wind direction an ionic wind generator with a point to plant geometry configuration. Electrode point was initially ionizes around the point. The positive ions that have been generated in the ionization zone will be rejected by the electrode point (positive) and towards the field electrode (negative). Positive ions moving in the direction (ionic wind) will make deformation on the surface of the dielectric fluid (lubricating oil). In lubricating oil, the molecules will form an electric polish. Figure 5a and figure 5b shows photo of lubricating oil with ionic wind for (a) new lubricating oil (b) used lubricating oil. In these figures the deformation of lubricating oil were presented. The wind direction can be determined by measuring the angelic characteristic (θmax) of the wind ion (called the wind direction angle). This ionic wind makes the surface deformation of the lubricating oil. The directional angle of the ion wind flow is formed when a voltage is applied to the reactor in the corona discharge zone. It can be assumed that, all charge transport through the gap is carried out by charged particles having the same polarity (unipolar)

(a)



(b)

Fig 5:- (a) New lubricating oil (b) used lubricating oil EHD Flow phenomena

The polarization that occurs on the surface of the lubricating oil causes the surface of the oil in the high electric field zone to turn into lumps. Lubricating oil lumps can be seen in figure 5.

In figures 5 (a) and (b) there are differences, these differences can be seen in the oil lumps. The lumps of new lubricating oil are larger than used lubricating oil, this is because used lubricating oil contains metal elements when it is used in motor vehicles. The point electrode provides a positive potential which causes negative charges such as negative ions and electrons to be attracted towards the point electrode and repel positive charges such as positive ions. The repulsion of positive ions from the point electrode creates an electrical phenomenon in the form of "wind" coming from the point electrode. In this study, EHD flow will appear if the applied voltage exceeds the corona threshold voltage.

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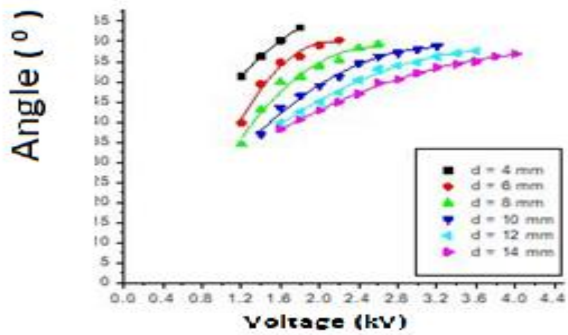
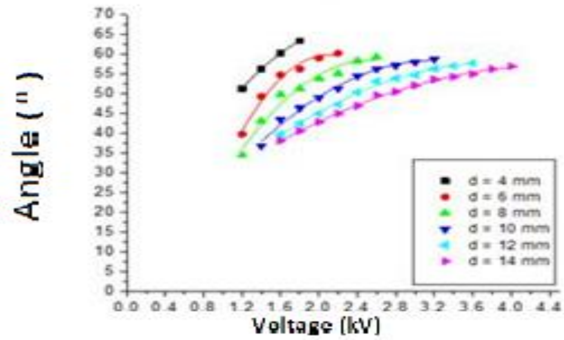
D. Determining the Angle of Ion Wind Direction in Electrohydrodynamic Phenomena

Determination of the EHD flow direction angle is influenced by the radius circle deformation of the EHD flow ® and the distance between the electrodes (d). Figure 6 is a graph of the relationship between the EHD flow direction angle and the voltage.



(a)



(b)

Fig 6:- (a) Used lubricating oil (b) new lubricating oil. Effect of voltage on ion wind angle

Figures 6 (a) and (b) show that the value of the EHD flow direction angle increases when the voltage is increased, but will reach the saturation point in the corona discharge area. The maximum angle value of the two lubricating oils will not reach 65^0 [2]. This can be seen in Figure 7 (a) at the distance between the electrodes (d) = 4 mm, the value of the maximum EHD flow direction angle is only at an angle of 64.8^0.

Comparison of the relationship between the EHD flow direction angle and the distance between the electrodes can be seen in Figure 6

In figure 7 there is a comparison between used lubricating oil and new lubricating oil, the relationship between the angle of the direction of the EHD flow and the distance between the electrodes at a fixed voltage of 1.6 kV. In used lubricating oil the value of the EHD flow direction angle is higher than that of new lubricating oil [2].

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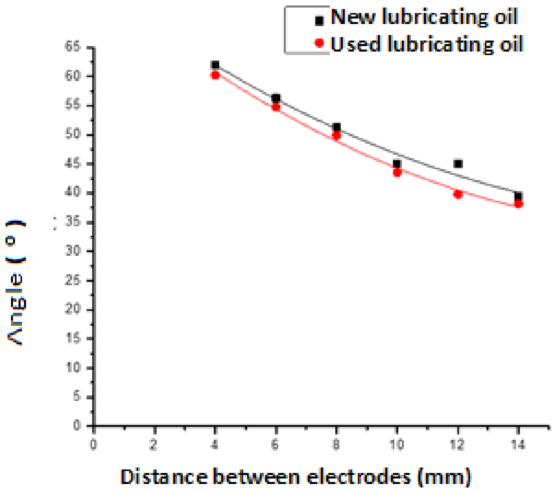
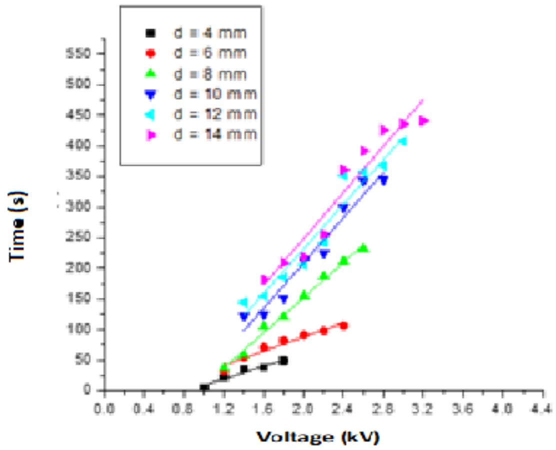


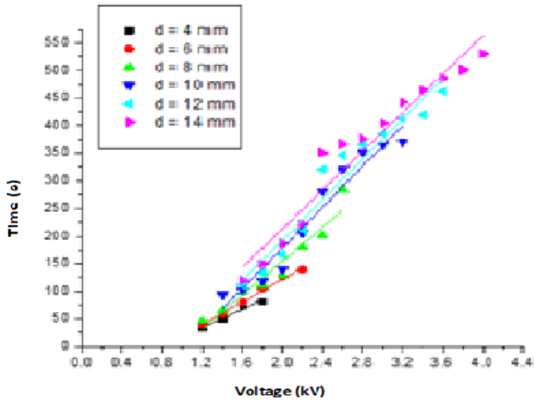
Fig 7:- Comparative graph of the relationship between the ion wind direction angle as function of the distance between the electrodes for new and used lublicant oil at a voltage (V)=1.6 kV

E. Analysis of Lubricating Oil Fusion Time After Termination of the Outside Field

When the voltage is turned on, a circle is formed in the middle of the lubricating oil, this is due to the EHD flow. After the voltage is turned off, the lubricating oil reassembles, and the circle deformation will disappear again. The time it takes for the lubricant oil to reassemble (loss of circle deformation) is largely determined by the distance and the applied voltage. The graph of the effect of applied voltage on the lubricating oil reassembly time can be seen in Figure 8. In figure 8 it can be seen that the higher the voltage, the longer the lubricating oil reassembly time. This is due to the increasing number of polarized lubricating oil molecules, resulting in a larger induced dipole moment. Previous research has also shown the same thing [2].



(a)



(b)

Fig 8:- (a) Used lubricating oil (b) new lubricating oil. Effect of stress on union time

The comparison of the two graphs can be seen in Figure 9

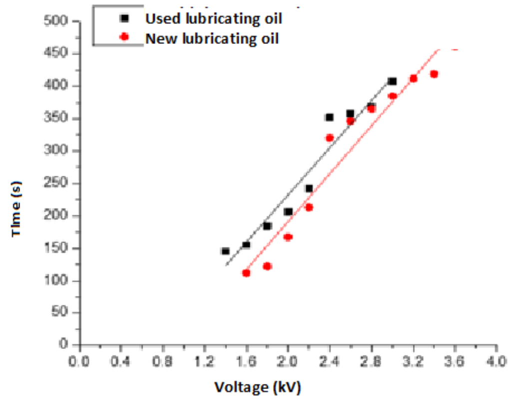


Fig 9:- Graph of the difference in the effect of voltage on the union time at the distance between the electrodes (d) = 12 mm

In Figure 9 it can be seen that the coalescence time of used lubricating oil is longer than that of new lubricating oil. This is due to the viscosity of the lubricating oil, the thicker it is, the faster the fusion time will be.

IV. CONCLUSIONS

Characterization of current as a function of voltage obtained current is a quadratic function of the voltage. The current as a function of voltage at the distance between the electrodes remains the largest without the sample, followed by the sample with used lubricating oil and the smallest with the new lubricating oil sample. The value of the EHD flow direction angle is smaller when the distance between the electrodes is getting bigger and the EHD flow direction angle is getting bigger when the voltage is increased. The value of the EHD flow direction angle in used lubricating oil is greater than that of new lubricating oil, for the same treatment of the distance between the electrodes and the voltage. The EHD flow sweep radius of used lubricating oil is greater than that of new lubricating oil. The incorporation time of new lubricating oil is faster than used lubricating oil.

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