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Comparative Study of Different Phenomena in Liquid Dielectrics at Different Gap Distances

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Abstract: The success of any electrical system lies in its insulating system performance. Petroleum based mineral oils are the generally used fluids for electrical insulation and heat transfer. But they are non-biodegradable. Vegetable oils obtained from seeds, flowers and vegetables are biodegradable, non -toxic, environmental friendly and benign to aquatic or terrestrial. The objective of this paper is to analyse the breakdown voltage and physical viscosity, flash point and fire point of sunflower oil, palm oil and mineral oil with and without moisture in them at different gap distances.

Keywords: HV (high voltage), BD (breakdown), Breakdown strength , Vegetable oils, Flash point and fire point.

I INTRODUCTION

Insulating liquids are extensively used in electrical apparatus which are operating in distribution and transmission systems. The function of electrical equipment strongly depends on the conditions of liquid dielectric. Liquid dielectrics are used in the most expensive components in power systems like transformers and circuit breakers. A failure of these equipment would cause a heavy loss to the electrical industry. Insulation failures are the leading cause of transformer failures and thus the liquid dielectrics plays a major role in the safe operation of transformers. Conventionally petroleum based mineral oils are used in high power apparatus. Even though the mineral oils have excellent dielectric properties such as high electric field strength, low dielectric losses, good long-term performance and are obtained at reasonably low price, mineral oils or synthetic insulating liquids are usually non-biodegradable. In case of equipment failure , their decomposition is very slow and could cause serious contamination of soil and waterways .
In addition, petroleum products are eventually going to run out. So it is essential to find out the solution to the problems identified in the field of liquid dielectrics .Based on the above, the alternative for mineral oil that is vegetable oil , which is reliable, cost-effective and environmentally friendly are being used .
Before considering vegetable oils for liquid insulation applications, it is essential to investigate the electrical, physical and chemical characteristics of vegetable oils. After reviewing the previous research works on vegetable oils, in this research work the characteristics of extra virgin sunflower oil, palm oil and mineral oil have been analysed and the results are compared with the same oils containing moisture.

Insulating liquids used in this work
1.Mineral oil
2.Sunflower oil
3.Palm oil

Breakdown in liquids dielectrics:
When a difference of potential is applied to a pair of electrodes immersed in an insulating liquid, a small conduction current is first observed. If the voltage is raised slowly and continuously, at a critical voltage a spark passes between the electrodes. The passage of a spark through a liquid involves the following.
1.Flow of a relatively large quantity of electricity, determined by the characteristics of the Circuit,
2. A bright luminous path from electrode to electrode,
3.The evolution of bubbles of gas and the formation of solid products of decomposition (if the liquid is of requisite chemical nature)
4.Formation of small pits on the electrodes,
5.An impulsive pressure through the liquid with an accompanying explosive sound.

Breakdown in contaminated liquids:
Breakdown in contaminated liquids takes place by three mechanisms[7]

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- Suspended Particle Mechanism
- Cavitation and Bubble Mechanism
- Stressed Oil Volume Mechanism

Since the BDV of transformer insulation oils reduces as the moisture content increases [2, 3]. High moisture content coupled with dissolved gases that have pressures higher than the ambient pressure also leads to bubbling effect in transformers [2, 3]. Therefore monitoring of moisture in oil is a routine maintenance procedure [4]. The presence of moisture in insulation oils is one of the leading causes of electrical breakdown because it increases the ionic conductivity of the oil hence lowering the breakdown voltage [5].

Viscosity of liquids

Viscosity is an important property of all liquids. The internal resistance offered by a liquid to the flow of one layer of fluid over a next layer is called viscosity[1]. This is due to the interrelation between the molecules of the fluid.

Factors affecting Viscosity

A substance's flow behaviour depends on three factors[1]:
1.The substance's inner- molecular– structure. The tighter
the molecules are linked, the more the substance will resist to its flow, i.e. the less it will be willing to flow.
2.The outside or external forces acting upon the substance that deform it or make it flow. Both the intensity of the external force as well as the duration has an influence. The external force can have the form of pushing a substance; the simplest form is gravity, which pulls all substances down to earth.
3.The ambient conditions. The temperature and the pressure when the substance is stressed by external forces.
4.Depending on these factors the substance flows and develops different types of flow.

Since moisture is one of the impurity it affects the viscosity of oils .In vegetable oils the viscosity increases after the presence of moisture because the intermolecular force of attraction is more for vegetable oils. Whereas in mineral oil viscosity decreases because of the lesser intermolecular forces.

Flash point and fire point of liquids:

The flash point is defined as the least temperature at which the liquid can evaporate to form an ignitable mixture in air. Measuring a liquid's flash point requires an ignition source. At the flash point, the vapour may cease to burn when the source of ignition is removed[1]. The fire point is the temperature at which the vapour continues to burn after being ignited. Both flash point and fire point are not related to the temperature of the ignition source or of the burning liquid, which are much higher. The flash point gives the description on the characteristic of liquid fuel, and it is also used to help to find the fire hazards of liquids. ―Flash point refers to both flammable liquids and combustible liquids.

Experimental procedure:

Breakdown voltage test:

The schematic diagram of the experimental setup which was used to assess the breakdown voltage of oil is shown in Figure 1. The test kit consists of one rectangular test cup made up of glass. The test cup consists of two sphere shaped electrodes of 12.5 mm diameter and there are two screws by which the gap between the spheres can be adjusted
Initially the distance between the electrodes was maintained as 2.5 mm and the test cup was filled with the mineral oil. High voltage AC supply was gradually raised at a rate of 2kV/s till the breakdown takes place[6]. A time interval of 2 minute is used between consecutive breakdowns. This test was carried out for all oils with and without moisture, at different electrode gap distances of 2.5 mm and 3.5mm gap (fig2,fig3) and corresponding breakdown voltage was recorded.

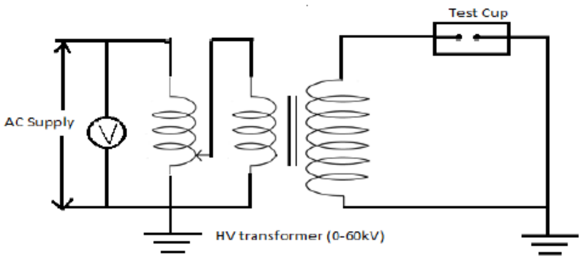

Fig1.Experimental setup for breakdown voltage measurement

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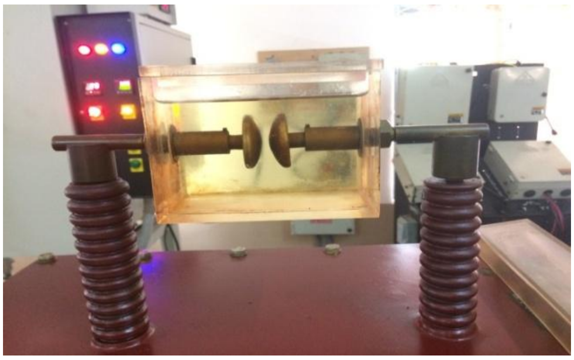

Fig2: Gap distance between the electrodes is 2.5mm

Fig3: Gap distance between the electrodes is 3.5mm

Viscosity test:

Fig4: Cannon –Fenske viscometer

Fig5: Viscometer tube

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Fill the required liquid in the Cannon-Fenske viscometer Tube no. 100 (Direct type) to bulb marked at top close the tube hold the viscometer tube in the Viscometer-water-Bath apparatus and heat to 40^0 C and maintain the temperature for a period of 20-30 minutes the above process is done so that the oil will obtain the prescribed temperature during the testing after 30minutes open the tube and simultaneously start the stopwatch .Stop the stopwatch once the oil flow reaches the bottom of the mark in the bulb. Note the seconds on the stopwatch
The time taken for the liquid to flow through the capillary tube can be converted directly to a Kinematic Viscosity using a simple calibration constant provided for each tube.
Kinematic Viscosity Cst = (number of seconds) × (Standard factor of the bulb of the viscometer tube used for testing)

Flash point and Fire point test:

Fig6: Pensky Marten Flash and Fire point detector

The liquids were poured up to the mark indicated in the flash point apparatus, t the oil was heated at regular interval and the oil was stirred and the temperature at regular period was noted. External fire was introduced at regular period till a flash was observed ,once the flash is observed the temperature at the time of flash was noted which is the flash point of liquid.

Flash point=Noted flash temperature.

By turning the valve to the fire point side of the apparatus the temperature at which the oil continues to burn was noted which is the fire point.

RESULTS AND DISSCUSSIONS

The breakdown voltages for different oils without moisture at a gap distance between the electrodes of 2.5mm are shown in Fig7.

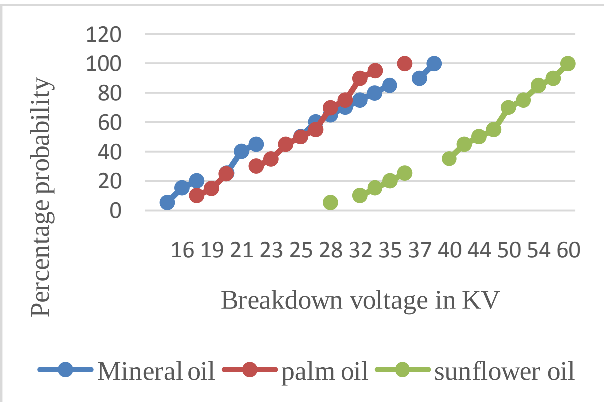

Fig7:Distribution of breakdown voltages at gap distance of 2.5mm for oils without moisture

The breakdown voltages for different oils without moisture at a gap distance between the electrodes of 3.5mm are shown in Fig8.

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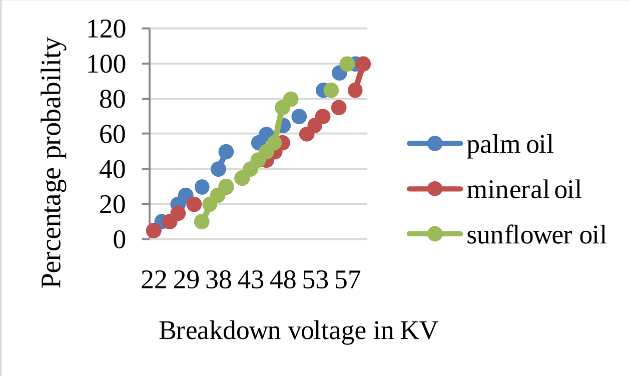

Fig8:Distribution of breakdown voltages at gap distance of 3.5mm for oils without moisture

We can observe from the graph that the oils without moisture at a gap distance of 2.5mm the breakdown voltages starts from 15KV(Mineral oil), 17KV(Palm oil) and 28KV(sunflower oil) . For a gap distance of 3.5mm for oils without moisture the breakdown voltages starts from 22KV(mineral oil), 23KV(palm oil) and 36KV(sunflower oil). Hence we can say that as the gap distance between the electrodes increases the breakdown voltage increases which is an advantage. The breakdown voltages for different oils which contain moisture at a gap distance between the electrodes of 2.5mm are shown in Fig9.

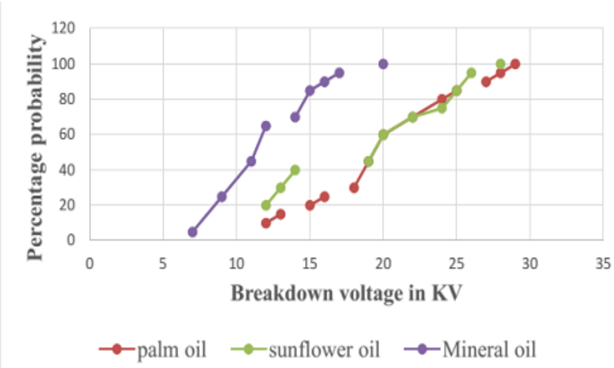

Fig9:Distribution of breakdown voltages at gap distance of 2.5mm for oils which contain moisture

The breakdown voltages for different oils which contain moisture at a gap distance between the electrodes of 3.5mm are shown in Fig10.

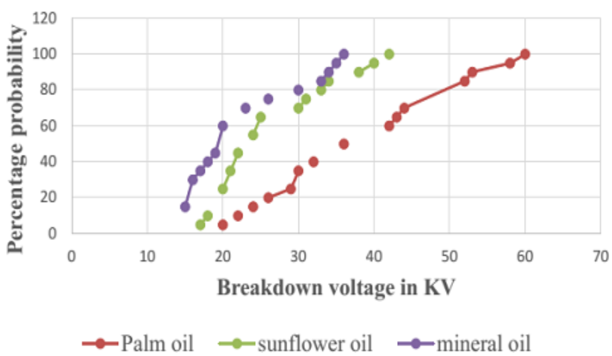

Fig10: Distribution of breakdown voltages at gap distance of 3.5mm for oils which contain moisture.

From the graph we find that at a gap distance of 2.5mm for oils which contain moisture the breakdown voltage starts from 7KV (mineral oil), the breakdown voltage of sunflower oil starts from 12KVand the breakdown voltage of palm oil starts from 12KV. For the gap distance of 3.5mm the breakdown voltage for oils starts from 15KV(mineral oil), the breakdown voltage of sunflower oil starts from 17KVand the breakdown voltage of palm oil starts from 20KV. The presence of moisture reduces the breakdown voltages of oils and they breakdown very soon compared to oils without

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moisture. Hence the oils without moisture are better dielectrics when compared to that of oils which contain moisture. We can also say that even when the oils contain moisture vegetable oils are better dielectrics than mineral oil. The breakdown strength of both oils without moisture and oils which contain moisture at a gap distance of 2.5mm are shown in Fig11.

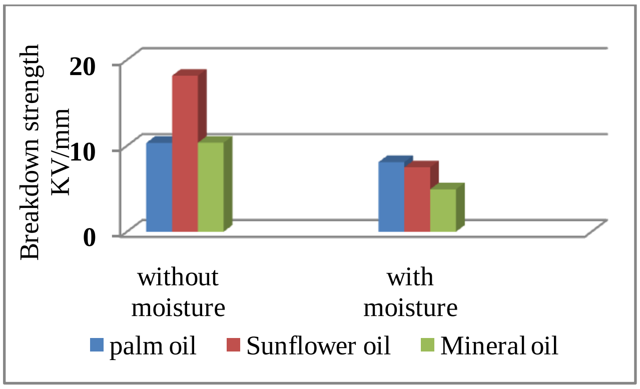

Fig11: Breakdown strength of different oils without moisture and oils which contain moisture at d=2.5mm

The breakdown strength of both oils without moisture and oils which contain moisture at a gap distance of 2.5mm are shown in Fig12.

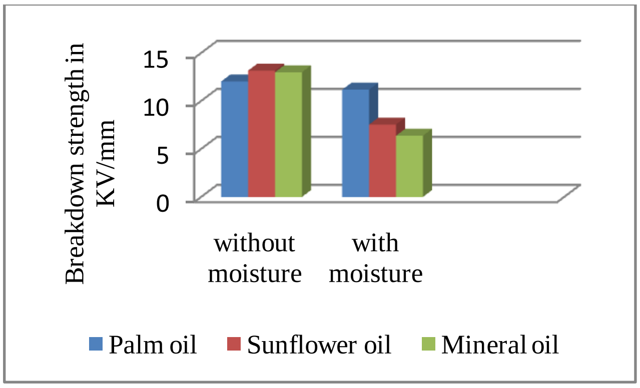

Fig12: Breakdown strength of different oils without moisture and oils which contain moisture at d=3.5mm

From the graph we can say that the breakdown strength of the oils increases as the gap distance between the electrodes increases. In oils without moisture at a gap distance of 2.5mm sunflower oil is better dielectric and at gap distance of 3.5mm also sunflower oil is a better dielectric.
When the oils are contaminated at both gap distance of 2.5mm and 3.5mm palm oil is a better dielectric. Hence it is proved that vegetable oils are better dielectric when compared to mineral oil even when they contain moisture.

Viscosity test results:

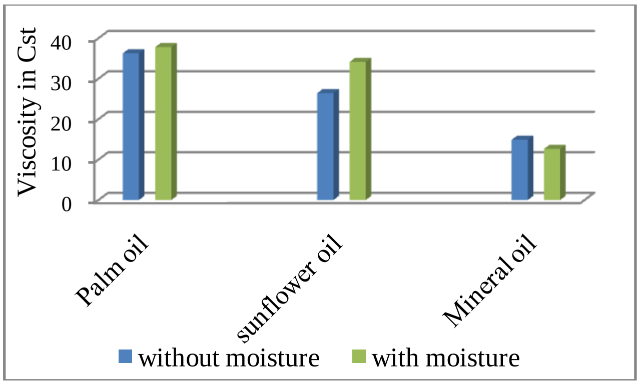

Fig13: Viscosity of oils without moisture and oils which contains moisture

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For comparison, the viscosity of oils at 40^0c was considered here. This clearly shows that viscosity of oils increases for oils which contains moisture. This due to the intermolecular forces in the liquids.. However compared to mineral oil, sunflower oil and palm oil shows higher viscosity when they contain moisture.

Flash and Fire point results:
Fig13 shows the flash point of all oils without moisture and with moisture

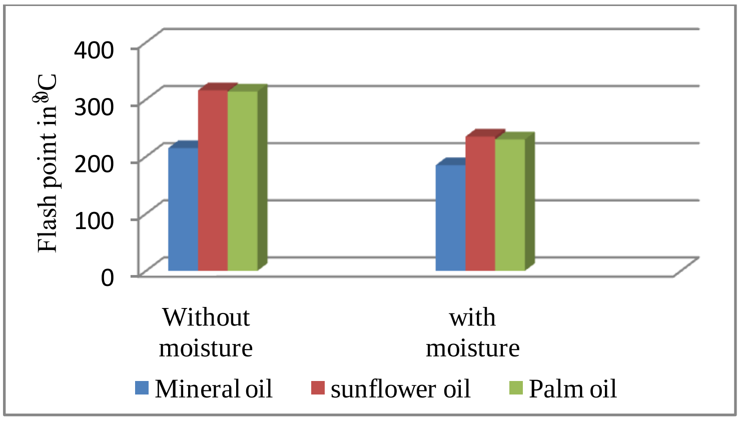

Fig13. Comparison of flash points.

From the graph we can say that the oils which do not contains moisture has larger flash point when compared to oils which contains moisture. So oils without moisture will ignite late when compared to oils which contain moisture.

Fig14 shows the fire point of all oils without moisture and with moisture

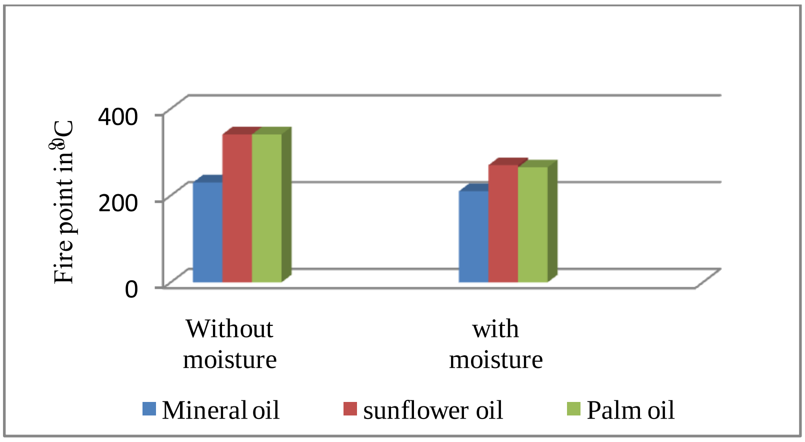

Fig14. Comparison of fire points.

From the graph we can say that the oils which do not contains moisture has larger fire point when compared to oils which contains moisture. So oils without moisture will ignite and burn late when compared to oils which contain moisture.

CONCLUSION

Liquid dielectrics are used in the most expensive components in power systems like transformers and circuit breakers.In this work we are finding the breakdown voltages for three kinds of oils with and without moisture at gap distances of 2.5mm and 3.5mm . We have proved that the breakdown voltages of oils increases as the gap distance between the electrodes increases. And we have also proved that the oils without moisture are better insulators than those of oils with moisture. The flash point and fire point of oils without moisture are greater when compared to the oils with moisture hence oils without moisture are good. This work also examined that vegetable oils(palm oil and sunflower oil) are better insulators than mineral oil when they contain and do not moisture .

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