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Experimental Investigation on Vegetative Oils under Accelerated Thermal Ageing against Their Dielectric Strength

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ABSTRACT

Insulation is one of the most important parts in high voltage apparatus such as power transformer. Most power transformer use liquid insulation material, known as power transformer oil. Petroleum-based oil so called mineral oil has been used for many years as power transformer oil. This is due to its high dielectric field strength, low dielectric loses and good long-term performance. This research work has been carried out to investigate the effect of thermal accelerated ageing on electrical properties for several vegetative-based oils. The oil samples that have been used in this research work are soy bean-based oil (FR3) and commercial palm-based oil (PFAE). As comparison, Hyrax mineral oil has also been investigated. The results revealed that vegetative-based oils have as well as dielectric strength compared with mineral oil. It was found that the dielectric strength for all oil samples decreased when undergo the thermal accelerated ageing process.

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1. INTRODUCTION

Petroleum-based oil so called mineral oil is the common insulating liquids that has been used for centuries due to its high dielectric properties, low viscosity, and inexpensive. However, it lacks in the ability to comply with the environmental and safety laws. Due to these deficiencies concern, and cost considerations on its long term working life span, many researches are being done to replace the use of mineral oil with biodegradable type of insulation oil.

Nowadays, researchers are actively searching for new types of insulating material, which are more environmental friendly. Therefore, this research work has been carried out to investigate the electrical properties and effect of thermal accelerated ageing against the electrical properties for several vegetative-based oils. During real operation, insulating oil is subjected to heat, oxygen and electrical discharge, which may lead to its degradation. Basically, the rate of aging is normally a function of temperature and moisture. Hence, this process is carried out in order to investigate the rate of degradation of the oils.

Many researchers have been investigating on this field [1]-[3]. However, effect of accelerated thermal ageing on vegetative oils is not widely reported. The main objective of research work is to investigate the effect of accelerated thermal ageing on vegetative oils as electrical insulation.

2. RESEARCH METHOD

2.1. Sample Preparation

The vegetative oil samples that have been used in this project are soy bean-based oil (FR3), palm olein oil, and commercial palm-based oil (PFAE). As comparison, Hyrax mineral oil as commercially used for transformer oil has also been investigated. In thermal ageing process, the samples were heated in the oven under 130^{o}C with duration of 50 hours.

2.2. Experiment

The dielectric strength test for non-aged and aged sampled were performed using test cell accordance with IEC60156 standard where the electrode gap was set to 2.5mm. The experimental procedure and detail about the dielectric strength test have been reported in our previous research works [3]-[5]. Figure 1 shows the oil sample inside the test cell which is used in this research work. The sample oils were filled for about 500 ml inside the test cell. Figure 2 shows the schematic diagram for dielectric strength test of oil samples. One test was repeated ten times for each sample.

Figure 1. Test cell filled with oil sample

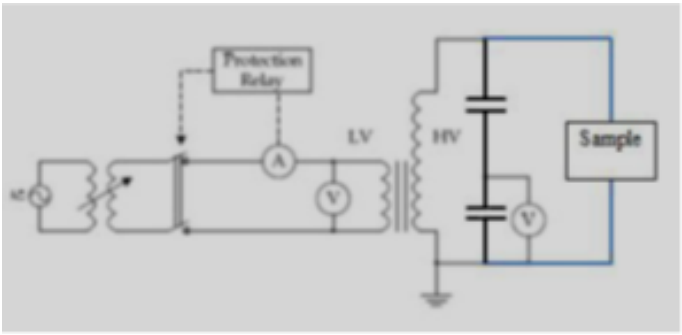

Figure 2. Electrical schematic diagram for dilectric strength test

3. RESULTS AND ANALYSIS

Figure 3 shows the average dielectric strength of all vegetative and mineral oil samples for new and aged condition. As can be seen clearly from the figure, soy bean-based oil (FR3) has the highest dielectric strength for new and aged condition compared to other oil samples.

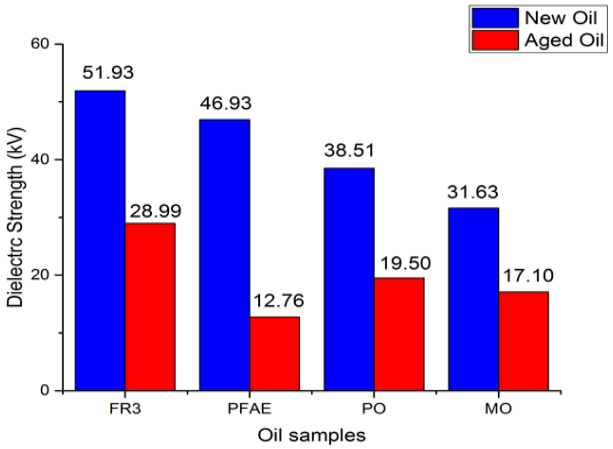

Figure 3. Average dielectric strength values of new and aged oil samples

Figure 4 shows the Weibull probability plot of dielectric strength for soy bean-based oil sample. It was found from the plot that the probability estimation of dielectric strength at 63.2% is 51.93 kV (New) and 28.99 kV (Aged) for soy bean-based oil sample (FR3).

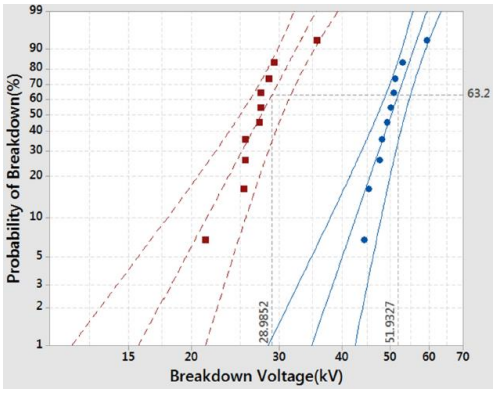

Figure 4. Weibull probability plot of the dielectric strength for soy-based oil sample (FR3)

Figure 5 shows the Weibull probability plot of dielectric strength for palm-based oil sample. It was found from the plot that the probability estimation of dielectric strength at 63.2% is 46.93 kV (New) and 12.76 kV (Aged) for palm-based oil sample (PFAE).

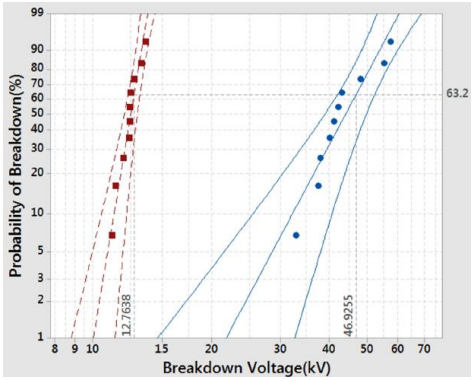

Figure 5. Weibull probability plot of the dielectric strength for palm-based oil sample (PFAE)

Figure 6 shows the Weibull probability plot of dielectric strength for palm olein oil sample. It was found from the plot that the probability estimation of dielectric strength at 63.2% is 38.51 kV (New) and 19.50 kV (Aged) for palm olein oil sample.

Figure 7 shows the Weibull probability plot of dielectric strength for mineral oil sample. It was found from the plot that the probability estimation of dielectric strength at 63.2% is 31.63 kV (New) and 17.10 kV (Aged) for mineral oil sample (Hyrax).

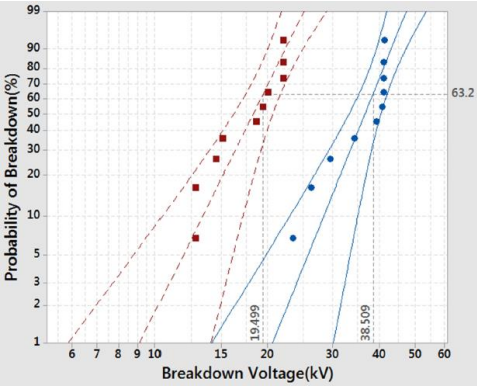

Figure 6. Weibull probability plot of the dielectric strength for palm olein oil sample

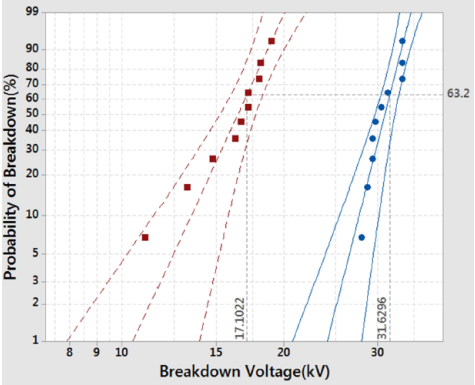

Figure 7. Weibull probability plot of the dielectric strength for mineral oil sample (Hyrax)

It was found from the experimental works that soy bean-based oil sample (FR3) has the highest dielectric strength (breakdown voltage) in new and aged condition compared to the other oil samples. While, mineral oil (Hyrax) has the lowest dielectric strength in new condition compared to the other samples. It might be the mineral oil which is used in this work has been deteriorated due to storage process in its container. The dielectric strength of all oil samples decreased after having accelerated thermal ageing. Palm-based oil (PFAE) has the lowest dielectric strength in aged condition compared to the other samples. The decrease in dielectric strength indicates that the insulation oils will deteriorate with time when they are under high operating temperatures. Thus the quality of the insulation oil degrades with sustained thermal stress [6]. All vegetative oil samples have high dielectric strength as requested in IEC60156 standard (above 30kV). It was also found that the dielectric strength for all oil samples decrease when having thermal accelerated ageing process. This is due to chemical reaction that occurs at 130^{o}C that cause the degradation of the oil samples.

4. CONCLUSION

Effect of accelerated thermal ageing on electrical properties of vegetative oil samples has been successfully investigated in this research work. Several importance findings are followings. All vegetative oil samples have high dielectric strength as requested in IEC60156 standard (above 30kV). It was also found

that the dielectric strength for all oil samples decrease when having thermal accelerated ageing process. This is due to chemical reaction that occurs at 130^{o}C that cause the degradation of the oil samples. Further research works in investigating other electrical properties such as partial discharge characteristics and dissipation factors are necessary.

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