

PERFORMANCE OF INSULATION TESTING FOR POWER TRANSFORMER BY USING MIXTURE OF REFINED BLEACHED DEODORIZED (RBD) CORN AND MINERAL OIL

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Abstract

Transformer is one of the most important equipment in electrical power system. Nearly, all high voltage transformers are filled with oil to act as cooling medium and insulator. Generally, petroleum-based mineral oil is used as transformer oil. However, due to environmental concern and life-cycle of mineral oil, renewable resource such as corn oil is chosen as the best option to replace the mineral oil. Past researches have shown that corn oil have an equivalent dielectric properties to substitute the mineral oil as liquid dielectric in electrical power transformer. However, the kinematic viscosity does not fulfill the IEC 60296 standard requirements and need to be improved. This research was carried out the detailed study on dielectric properties of mineral and Refined Bleached Deodorize (RBD) corn oil with follow the method of international electro technical commission number. The results shows that the data of the corn oils is critically compared with that of the mineral oil and appropriate causes for similarities and differences have been discussed. The properties has been observed in this research are dielectric strength, dissipation factor ($\tan \delta$), relative permittivity (dielectric constant), kinematic viscosity and breakdown voltage. The comparison results between the mineral oils and RBD corn oil has come out with suggestion that corn oils also can be used as transformer oil.

Keywords: Breakdown voltage; dissipation factor ($\tan \delta$); kinematic viscosity;

1.0 INTRODUCTION

Power transformers are made up of a large proportion of insulating materials. Generally, petroleum based mineral oil has been used as the main source of insulation oil especially for power transformers [1]. These materials will slowly degrade due to the best insulation process under normal operating conditions [2]. Hence, operating within specified conditions and temperature, the equipment will be able to provide reliable service for many years.

There are three basic types of electrical insulating, which is solid, liquid and gas [3]. These materials are widely employed in electrical network components such as circuit breakers, transformers, cables and capacitors. Liquid dielectrics are used for filling transformers, circuit breakers and as impregnate in high voltage cables and capacitors [4]. This research will be conducted with electrical insulation of oil that used in transformer.

The three most important properties of liquid are dielectric strength, relative permittivity dielectric constant and the electrical conductivity [5]. Other important properties mixture of oil included the viscosity, dissipation factor ($\tan \delta$) and flash point. The important factors that affect the dielectric strength of oil are the presence of fine water and the fibrous impurities [6]. Therefore, when oils are used for providing electrical insulation, the oil should be free from moisture, products of oxidation and other contaminants [7].

From this research, RBD Corn oils is biodegrade quickly and completely, and also exhibit very low or no toxicity as compared to mineral oils [8]. This is mainly due to the fact that RBD corn oil of dielectric fluids do not contain halogens, polynuclear aromatics, volatile or semi-volatile organics, or other compounds that can be present in mineral oils or other dielectric fluids [9]. In addition, they are environmentally friendly such as renewable, non-toxic and biodegradable [10].

Table 1. Properties of Mineral Oil

PROPERTIES	METHOD	VALUE
Kinematic Viscosity, cSt 40 °C 100 °C	ISO 3104	9.24 2.36-3.0
Flash Point, °C	ISO 2719	145
Pour Point, °C	ISO 3016	-50
Density, kg/dm ³ 20°C	ISO 3675	0.875-0.88
Water Content, ppm	IEC 60814	<20
Breakdown Voltage, kV	IEC 60156	>50
Dissipation Factor	IEC 60247	0.005

Furthermore, RBD Corn oils also can used in transformers oil due to their electrical insulating property that becomes limited by their breakdown on the application of high voltage across them. So

that RBD corn oil cans mixture with the mineral oil to make the best insulation in transformer oil. This breakdown voltage is highly influenced by the impurities like humidity, gases and particles present in the oil. This gives rise to the tendency for comparing them with others by controlling the impurity contents.

2.0 EXPERIMENTAL

A. Sample of Mixture Oil

Sample used in the experiment was mineral oil and RBD corn oil. There are six sample is used that contains different percentage mixture of mineral and RBD corn oil. The percentage mixture of oil divided to six samples as in Table 2.

Table 2. The Types and Specification of Sample That Be Used In Experiment

Types of Sample	Specification
Sample 1	100% RBD Corn Oil
Sample2	100% Mineral Oil
Sample 3	80% RBD Corn Oil + 20% Mineral Oil
Sample 4	60% RBD Corn Oil + 40% Mineral Oil
Sample 5	40% RBD Corn Oil + 60% Mineral Oil
Sample 6	20% RBD Corn Oil + 80% Mineral Oil

The range of temperature is used between 40 to 60°C during testing the insulation of transformer. The properties that be used for this range temperature is to testing the voltage breakdown and dielectric dissipation factor ($\tan \delta$). In addition, for viscosity test, the temperature for testing is at 40°C.

Before develop this project, it is very important to study the insulation of transformer and research about dielectric properties that need to test for the oil. This research contains three different properties to test which is breakdown voltage, dissipation factor and viscosity.

B. Preconditioning Process

Precondition process of oil samples was done before doing the experimental process. A magnetic stirrer with hotplate is used during the precondition process. The temperature is maintained to 40°C to avoid the vaporization of water and the samples is stirred in the range of 5 to 10 minutes before the samples is put into the test cell for experiment process. The equipment used is shown in Fig. 1.



Fig.1. Preconditioning Process

C. Kinematic viscosity

The resistance of fluid to flow and shear stress due to gravity. The kinematic viscosity test was measured by these procedures. The measurement was using Automated Viscometer Houillon VH2 and the temperature was set up at 40°C according to basis for the (ISO 3448 kinematic viscosity grading system (International Standard). Approximately 10ml of oil mixture carefully pumped into three glass capillary tubes viscometer by using syringe and rubber tube to avoid the presence of air bubbles. The time from point from point A to B or from point B to C was recorded. The position of point A, B and C is shown in Fig. 2.

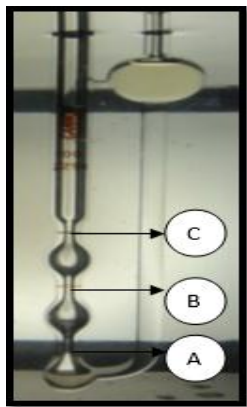


Fig. 2. Glass capillary viscometer

D. Breakdown Test

The test of breakdown voltage is performed according to IEC 60156 standard which stated that the AC voltage with 50 Hz of frequency needs to be injected in the insulation fluid by an increasing rate of 2kV/s. The gap between the electrodes must be 2.5 mm + 0.05mm based. The test cell used in the experiment is shown in Fig. 3

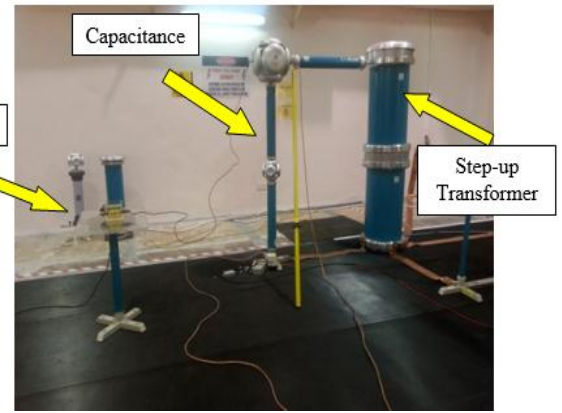


Fig.3. Breakdown Testing

E. Dissipation Factor ($\tan \delta$) Test

The dielectric dissipation factor ($\tan \delta$) measurement in this project follows the IEC 60247 standard including preparation of measurement tool. The test cell is injected with increasing steps of 2kV test voltage.

3.0 RESULTS AND DISCUSSION

All result for six samples of different mixture of mineral and Refined Bleached Deodorize (RBD) corn oil has been obtained. The data from the dielectric property measurements which include the breakdown voltage, dielectric dissipation factor ($\tan \delta$) and viscosity are recorded and the data is presented in table and graph to be used for comparing the dielectric characteristics between six samples of different mixture of mineral and RBD corn oil. Finally yet importantly, analyses on each test samples that meet the properties of insulating oil are made.

According to the result, mineral oil meets the requirement of the standard compared to the RBD corn oil. This shows that Mineral oil is a better liquid insulating material for transformer. This is the reason why mineral oil is used widely in the whole world as transformer oil. However, the RBD corn oil is a new liquid insulating material that is more friendly to the environment compared to the mineral oil and will not depletion source.

This indicates the prospect of RBD corn oil to be further processed to get better dielectric properties and meet all requirements to be used as liquid insulating material. So that, in this paper that suggest to mixture the mineral oil with RBD corn oil to get the best insulation material for transformer oil.

A. Breakdown Voltage

The results of breakdown voltage measurements for six samples of different mixture of mineral oil and RBD corn oil for different temperature that is at 40 °C

to 60 °C are listed in Table 3. Three breakdown tests were conducted on each sample to obtain great results. Thus, the data obtained the average value to be more accurate result for breakdown voltages.

The results of each sample listed in Table 3 and the graph also plotted to shows the breakdown voltage. A graphic presentation of the breakdown voltage comparison between six samples versus the temperature is described in Figure 4.

It shows that the breakdown voltage of mineral oil was lower compared to the RBD corn oil. The samples of mixture with high percentage of RBD corn oil compare to mineral oil, breakdown voltage is slightly higher if compare with low percentage of RBD corn oil.

In addition, during experimental conducted for sample 1 and 3, some errors occur and the voltage not breakdown. It is because of the test result that the breakdown voltage increase gradually up only to 40 kV, which is the maximum applicable voltage by the equipment. So, the value of voltage breakdown can increase more than 40 kV.

Table 3. The Result Breakdown Voltage between Mixture of RBD Corn Oil and Mineral Oil

Specification	Tan δ				
	100% RBD Corn Oil	80% RBD Corn Oil + 20% Mineral Oil	60% RBD Corn Oil + 40% Mineral Oil	40% RBD Corn Oil + 60% Mineral Oil	20% RBD Corn Oil + 80% Mineral Oil
Temperature (°C)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
40	0.01604	0.01634	0.01749	0.01398	0.01138
50	0.02019	0.01957	0.01856	0.01582	0.01221
60	0.02675	0.02349	0.02966	0.01807	0.01326

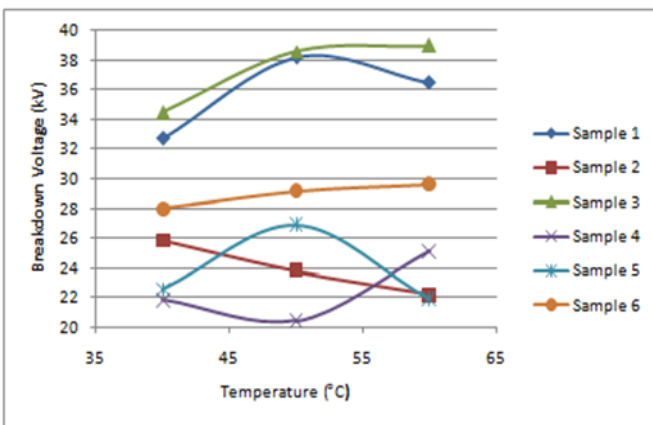


Fig. 4. Breakdown Voltage Vs Temperature

Furthermore, some errors occur during experimental is about the low voltage breakdown, this is because the effect of surrounding such as lab condition. The condition in lab that influences the temperature decrease faster in test cell. Test cell that

be used for testing uncovered and the temperature fast to decrease.

For sample that high breakdown voltage, the sound corona appears and the ICM compact show fast waveform. This happen to indicates that the breakdown to occur in the short of time. Corona is a phenomenon that has the capability for degrading insulators and causing systems to fail.

This result shows the potentiality of RBD corn oil to mixture with mineral oil in using as insulating liquid in transformer.

B. Dissipation Factor (Tan δ)

Generally, Dissipation Factor will measure the loss rate of power in a dissipative system. Good insulator should have the dissipation factor below 0.005. The tan δ results for five samples of different percentage mixture mineral oil with RBD corn oil are recorded with the different temperature which is 40 °C to 60 °C.

The following data show tan δ results for five samples shown below as in Table 4. Graph also plotted for five samples in Figure 5. The equipment use to measure the value tan δ is Capacitance and Tan δ Measuring Bridge. For each sample, the applied voltage used is 10 kV and it constant to take readings state became balance. The result of Tan δ recorded after the state balanced, then the duration time to state becomes balance about 4 seconds.

Table 4. The Result Tangent Delta Test between Mixture of RBD Corn Oil and Mineral Oil

Specification	Breakdown Voltage (kV)					
	100% RBD Corn Oil	100% Mineral Oil	80% RBD Corn Oil + 20% Mineral Oil	60% RBD Corn Oil + 40% Mineral Oil	40% RBD Corn Oil + 60% Mineral Oil	20% RBD Corn Oil + 80% Mineral Oil
Temp (°C)	1	2	3	4	5	6
40	32.67	25.83	34.46	21.80	22.53	27.96
50	38.67	23.80	38.56	20.43	26.90	29.16
60	36.67	22.16	38.93	25.13	21.86	29.63

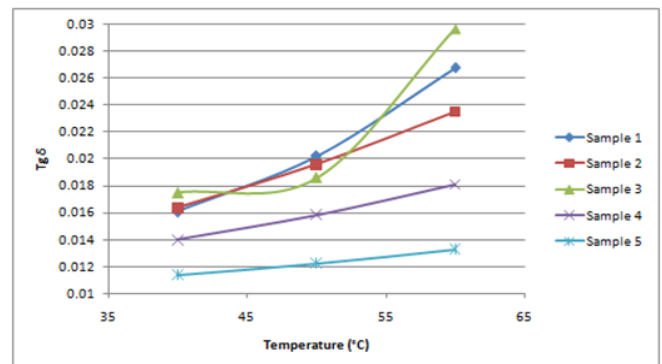


Fig. 5. Tan δ Test Vs Temperature

In previous research, the value $\tan \delta$ for mineral oil is 0.005. Based on Figure 3 shows, $\tan \delta$ results decrease when the sample of oil that contain the mixture of RBD corn oil lower than mineral oil. Since the value of $\tan \delta$ for sample 5 is lower than other sample, this indicates the possibility of application of this mixture for insulating material. So that, the mixture with RBD corn oil is suitable to use for insulating liquid in transformer.

C. Kinematic Viscosity

The kinematic viscosity of six samples which is mixture of mineral oil and RBD corn oil content was measured at temperature 40°C. The equipment that used to test viscosity is viscometer. The temperature set in this equipment during experimental is 40°C. Viscometer has four tubes to enter this liquid to check viscosity. In this paper, three tube that take as a reading and the result was recorded. Three tests were conducted on each sample to obtain great results. Thus, the value of viscosity that obtained tabulated in table. The data for all samples are listed in Table 5. Figure 4 shows the plotted graph of kinematic viscosity of six samples of different tube.

Table 5. The Result Viscosity Test between Mixture of RBD Corn Oil and Mineral Oil

Specification	Types of Sample	Viscosity Test (mm ² /s)		
		Tube 1	Tube 2	Tube 3
100% RBD Corn Oil	Sample 1	39.779	32.0950	32.0680
100% Mineral Oil	Sample 2	10.757	8.8117	8.7580
80% RBD Corn Oil + 20% Mineral Oil	Sample 3	31.211	25.464	25.8193
60% RBD Corn Oil + 40% Mineral Oil	Sample 4	24.358	19.9220	20.0633
40% RBD Corn Oil + 60% Mineral Oil	Sample 5	18.746	15.3107	15.3743
20% RBD Corn Oil + 80% Mineral Oil	Sample 6	12.624	10.4177	10.3980

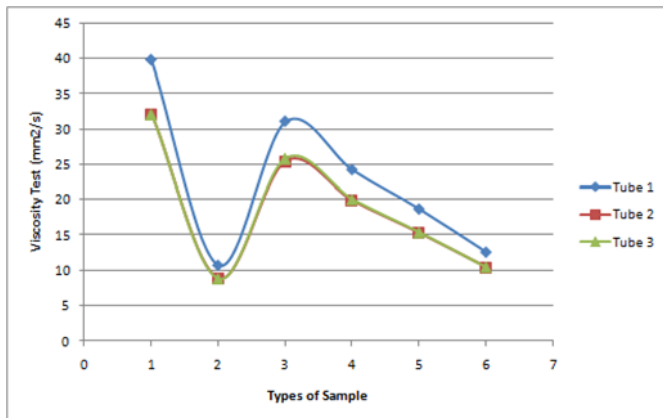


Fig. 4. Viscosity Test Vs Types of Sample

It is shown that the kinematic viscosity of mineral oil was under the limit of IEC 296 standards which is below than 16.5. Meanwhile, the kinematic viscosity of other sample of mixture was exceeded the standard limit.

However, one of mixture sample not exceeds the standards limit which is sample 6. This sample is content mixture higher percentages of mineral oil with lower percentage of RBD corn oil. The kinematic viscosity of different mixture was decreased with the increment of mineral oil ratio into RBD corn oil. This result shows a significant positive result of reducing the kinematic viscosity and RBD corn oil suitable to mixture with mineral oil to use for insulation transformer.

4.0 CONCLUSION

Based on the testing and research gathered from the laboratory high voltage and field performance for six samples, it can be concluded that, RBD corn oil can be a good choice as an alternative to the conventional mineral oil for power transformers.

In this paper, the breakdown voltage and dissipation factor ($\tan \delta$) for different sample of percentage oil occurs depends on temperature range between 40°C to 60°C. But the viscosity for six samples that fix the temperature at 40°C. Then, mixture of RBD corn oil and mineral oil is suitable to use as insulation for transformer.

As far as the long-term performances of power transformers are concerned, the recommendation are suggested is to analyze the aging aspects of treated RBD corn oil together with mineral oil which is how long it suitable for insulation of transformer. The duration time suggests is about 1 to 3 hours for six sample of different percentage of oil.

Besides that, the future recommendation about this project is need to replace new test cell. Test cell need to closed to prevent ambient air to enter and to avoid the temperature surrounding reduce the temperature in test cell. Also to avoid the error during testing happen.



Fig. 4. The New Type of Test Cell That Have A Cover Viscosity

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