

Electrical and Chemical Properties of New Insulating Oil for Transformer Using Pure Coconut Oil

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Abstract – *The petroleum based mineral oil has been used as the insulation for the transformer since a long time ago. Mineral oil acts as a cooling and insulating medium in transformer. Transformer mineral oil has been replaced by alternative oils such as synthetic oil and natural esters due to their biodegradability and environmentally friendly nature. Due to the environmental consideration, mineral oil is the poor biodegradability and future scarcity. It can cause the pollution and contaminate soil when a serious spill takes place. The mineral oil was extracted from the petroleum, which is going to run out in the future and the petroleum is non-renewable energy. The paper presents a study that has been carried out to investigate the performance coconut oil as an insulator of the transformer and to investigate the insulating properties of coconut oil. There are two aspects was considered, which are electrical and chemical properties. The parameters of electrical properties that have been investigated are breakdown voltage and resistivity. While, chemical properties are kinematic viscosity, flash point and water content. The study shows that pure coconut oil gave the best performance in chemical properties compare to mineral oil while coconut oil has potential to be used the alternative insulator of the transformer. Copyright © 2016 Penerbit Akademia Baru - All rights reserved.*

Keywords: coconut oil, power transformer oil, breakdown voltage, flash point

1.0 INTRODUCTION

Electrical insulator is a material whose internal electric charges do not flow freely, and therefore make it very hard to conduct an electric current under the influence of an electric field [1].

Insulating oil in an electrical power transformer is commonly known as transformer oil. It is normally obtained by fractional distillation and subsequent treatment of crude petroleum. That is why this oil is also known as mineral insulating oil. Transformer oil serves mainly two purposes one it is liquid insulation in electrical power transformer and two it dissipates heat of the transformer i.e. acts as a coolant. In addition to these, this oil serves other two purposes, it helps to preserve the core and winding as these are fully immersed in oil and another important purpose of this oil is it prevents direct contact of atmospheric oxygen with cellulose made paper insulation of windings, which is susceptible to oxidation [2].

There are several important properties such as dielectric strength, resistivity, flash point, kinematic viscosity and water content. These properties are considered when qualifying oil as the transformer oil. The high voltage heavily loaded transformer demand better quality of oil. While, at low voltages lightly loaded, transformer demand the high quality oil is not critical [2].

The transformer oil manufactures are desired to supply the customer with oil that gives good performance during operation. Transformer oil is expected to function as an insulating and cooling medium. The behavior of the oil can be related to its chemical and physical properties. It is very difficult to predict the transformer oil in actual field operations from the fundamental properties of the oil. Thus the behavior of the oil transformer must be considered, its behavior can be related to its molecular composition and physical properties. There are various other components like air, moisture and unsteady voltage which influence its performance [3].

1.1 Power Transformer Oil

Good transformer oil acts as a liquid insulation in an electrical power transformer and dissipates heat from the transformer as a cooling medium. The insulator helps preserve the core and windings of the transformer for they dipped in it. Due to the oxidation susceptibility of the cellulose paper insulation made for the both windings, primary and secondary, the transformer oil prevents direct contact of atmospheric oxygen [4].

Petroleum based mineral oil has been used since 1891 as transformer oil. In addition, the oil is not only used as a liquid insulation, but also as a coolant of the transformer. The petroleum based mineral oils have been used for insulation because of their excellent dielectric properties. This oil has been used since long time ago due to ability to self-cured to the situation leading to partial or total discharge [5]. Dielectric fluid act as cooling medium and insulation of appliances. The insulating oil fills up pores in fibrous insulation as well as the gaps between the coil conductors and the spacing between windings and the tank. Thus, the dielectric strength of insulation is increased [6]. The disadvantages of mineral oil are non-biodegradable and non-environmentally friendly. The mineral oil is low flash point, low breakdown voltage and difficulty of disposal after usage. Thus many researches have been carried to find the alternative of liquid insulating material as there friendly to the environment.

1.2 Pure Coconut Oil

Normally mineral oil is used as an insulator for the transformer, but nowadays, coconut oil has been shown to possess all the properties needed to function as an environmentally friendly replacement for mineral oil [7]. Coconut oil is a member of tropical oil, which also includes palm, cocoa and Shea nut oils.

Coconut oil is most of the other natural esters consist of triglycerides. Figure 1 shows a typical reaction occurring between glycerol and acid groups to form triglycerides. These triglycerides contain different fatty acid which might be saturated or unsaturated depending on the oil type [8].

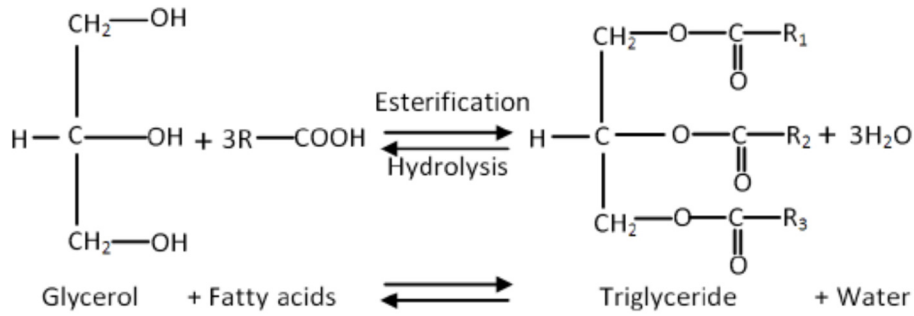


Figure 1: Chemical reaction between glycerol and fatty acid [8]

The Table 1 shown coconut oil contains a high percentage of saturate fat (C12:0, C14:0). Therefore, high pour point is the main advantage caused by the high percentage of saturated fat [4]. Table 2 shows some important properties of coconut oil. Most of the physical properties such as dielectric strength, viscosity, pour point, flash point and moisture are within the recommended limit of mineral by IEC 60296 [9]. According the Table 2, viscosity of coconut oil is higher than the recommended value; it is less than some of the vegetable oils.

Table 1: Acid composition in coconut oil and other vegetative oil

Fatty acid name R1,R2,R3		Coconut Oil	Rapeseed Oil	Soybean Oil	Sunflower (high oleic) oil
Scientific	Common name				
Caproic	C6:0	ND-0.7	ND	ND	ND
Caprylic	C8.0	4.6-10.0	ND	ND	ND
Capric	C10.0	5.0-8.0	ND	ND	ND
Lauric	C12.0	45.1-53.2	ND	ND-0.1	ND
Myristic	C14.0	16.8-21.0	ND-0.2	ND-0.2	ND-1
Palmitic	C16.0	7.5-10.2	1.5-6.0	8.0-13.5	2.0-6.0
Palmitoleic	C16.1	ND	ND-3.0	ND-0.2	ND-0.05
Margaric	C17.0	ND	ND-0.1	ND-0.2	ND-0.05
Heptadecenoic	C17.1	ND	0.5-3.1	ND-0.1	ND-0.06
Stearic	C18.0	2.0-4.0	8.0-60.0	2.0-5.4	2.9-6.2
Oleic	C18.1	5.0-10.0	11.0-23.0	17-30	75-90
Linoleic	C18.2	1.0-2.5	11.0-23.0	48.0-59.0	2-19
Linolenic	C18.3	ND-0.2	5.0-13.0	4.5-11.0	ND-0.3
Arachidic	C20.0	ND-0.2	ND-3.0	0.1-0.6	0.2-0.4

ND- non detectable, defined as $\leq 0.05\%$

Table 2: Comparison of physical properties of coconut oil and typical vegetative oil [4]

Property	Coconut oil	Vegetable oil	Uninhibited class I mineral oil
Dielectric strength(kV)	60	74	50
Viscosity (cSt at 40°C)	29	33-45	13
Pour point (°C)	23	-15 to -25	-40
Flash point (°C)	170-225	310-325	154
Specific gravity at 20°C	0.917	0.91-0.95	0.895
Moisture content (mg/kg)	1	50-10	1.5

2.0 EXPERIMENTS

There are five experiments that have been conducted in this project which are breakdown voltage, resistivity, kinematic viscosity, flash point and water content. The experiments are conducted to know the properties of test samples in term of electrical and chemical.

2.1 Breakdown Voltage

Breakdown voltage is to withstand voltage where the probability of failure at a given voltage. The higher values of breakdown voltage are needed to obtain the best insulation oil. The higher breakdown voltage can prevent breakdown of the oil under electrical stress. The breakdown voltage is tested refer to the international standard, IEC 60156 Determination of the breakdown voltage at power frequency [10]. The AC voltage with frequency 50Hz need to apply and voltage are uniformly increases within the interval 2kV/s. The sample was measured by using the spherical electrode with spacing of 2.5mm.

2.2 Resistivity

Resistivity is a measure of the materials ability to oppose electric current. The value of resistivity need to be high for obtain good insulation oil. The resistivity are tested refer to IEC 60247:2004 Measurement of relative permittivity, dielectric dissipation factor ($\tan \delta$) and d.c. resistivity [11].

2.3 Kinematic Viscosity

Viscosity is a measure of the fluid's resistance, generally viscosity decreases as the temperature is increased. Viscosity is a measure of particle bond strength. The heats are required to break the bond of these particles. The higher value of viscosity shows the higher the bond strength between particles. Viscosities of the oil sample were also confirmed by using a Viscometer. The purpose of this experiment to know the ability of the oil samples at temperature 40°C and 100°C.

2.4 Flash Point

The flash point is the lowest temperature at which a liquid can form an ignitable mixture in air at the surface of the liquid [12]. The lower value of flash point, the easier the material get ignite. The flash points refer to standard ASTM D93 by using Pensky- Marten Closed Cup Tester (PMCC). Pensky-Marten Closed Cup Tester is used to determine the flash point of viscous or film forming liquids. The value of flash point must be high to be good insulation oil.

2.5 Water Content

Normally the standard to measure the water content in any material is IEC 60814 [13]. The main sole of oil in the transformer is to which provide electrical insulation. When the moisture increase, the properties of oil will be reduced this affect the breakdown voltage. At the same time, the properties of oil are important when temperature fluctuates where, when the transformer cooled down and this resulted the oil having.

Many transformers contain the cellulose based paper which is being used the winding as an insulation. The moisture in present in paper insulation of the transformer winding, the insulation properties will be reduced. Moisture can reduce the electric field strength and can lead the harmful situation during breakdown.

3.0 RESULTS AND DISCUSSION

The results obtained from the experiment are presented in bar chart to illustrate and compare data between the samples. The basic criteria to be good insulating material are [14]:

1. The high value of breakdown voltage that may provide dielectric strength to prevent breakdown under electrical stress.
2. The high value of resistivity was required to oppose the electric current.

The experiment was done with 6 samples where 3 samples for mineral oil (Sample A, Sample B, and Sample C) while 3 samples for coconut oil (Sample D, Sample E, and Sample F).

3.1 Breakdown Voltage

From Figure 2, the graph shows that the higher value of breakdown voltage in this experiment is obtained from the sample B of mineral oil compared to other sample. Value of breakdown voltage for sample B of mineral oil is 24.18 kV. The lower breakdown voltage is obtained from sample F of pure coconut oil which is 14.25 kV. But sample E has the higher breakdown voltage compared to other samples of pure coconut oil which is 21.34 kV. That mean, the pure coconut oil can achieve higher breakdown voltage and suitable to be modified to be used as the insulating material of transformer.

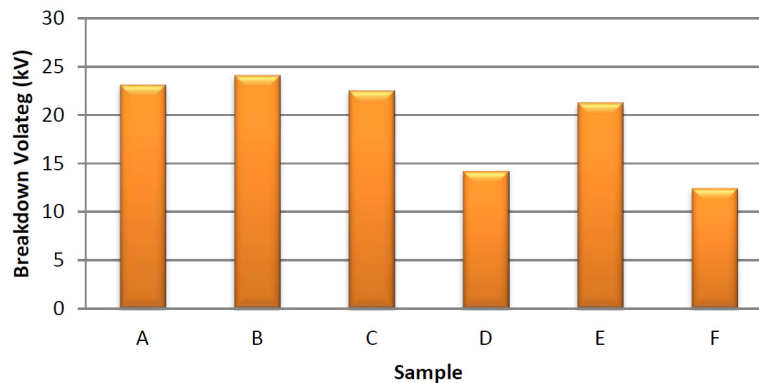


Figure 2: Graph for breakdown voltage

3.2 Resistivity

Resistivity of transformer oil is the ability to oppose the electric current flow. The higher value of resistivity gives a better insulation to withstand contact with oil without deterioration of physical properties. From the Figure 3, sample F of pure coconut oil have the higher value which is 17.52 GΩ-mm, followed by sample E which is 17.02 GΩ-mm. The lower value of resistivity is obtained from sample C of mineral oil which is 2.33 GΩ-mm. Surrounding humidity are influenced the resistivity value. The presence of contaminant particles will increase the resistivity of the oil. By comparing between mineral oil and pure coconut oil, pure coconut oil is suitable for transformer oil due to the highest value resistivity.

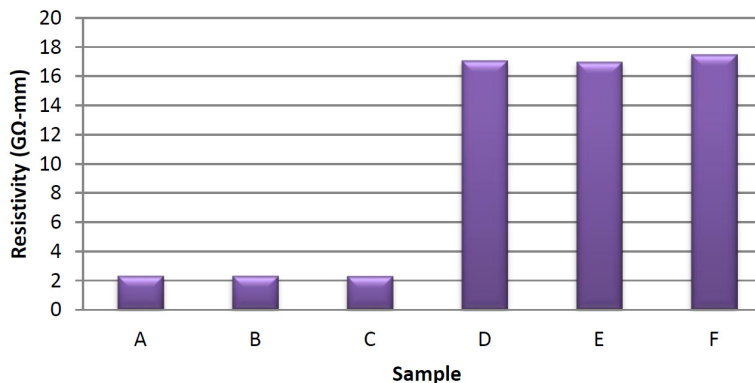


Figure 3: Graph for resistivity

3.3 Kinematic Viscosity

From Figure 4, sample B has lower kinematic viscosity compared to others sample of mineral oil at temperature 40 °C which equal 5.40 cSt. The graph shows the highest value of kinematic viscosity is pure coconut oil which is 17.00 cSt at temperature 40°C. Under the other temperature of 100 °C, sample E has the lower kinematic viscosity which equal 1.80 cSt. Meanwhile sample C has the highest kinematic viscosity value is given pure coconut oil which is 2.12 cSt.

The higher value of kinematic viscosity is not suitable to use as the insulator of transformer because it gives higher resistance to flow. The oil cannot transfer heat to the interior of the transformer. To achieve the better insulation, the insulating material should have a lower value of kinematic viscosity to allow easy heat transfer inside transformer due to the resistance to flow is lower. Pure coconut oil gives the lower value of kinematic viscosity compare to the mineral oil, therefore pure coconut oil is suitable use as the cooling agent in transformer.

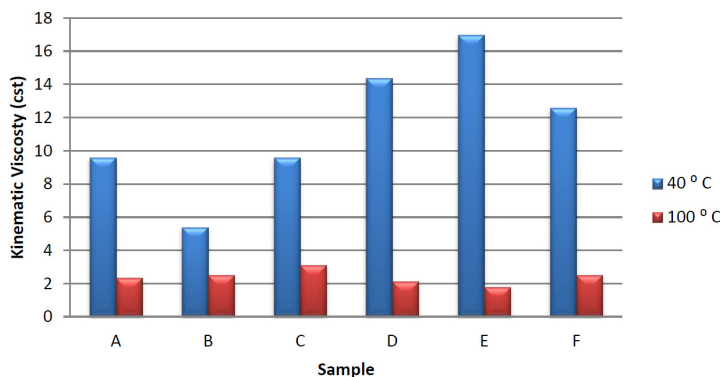


Figure 4: Graph for kinematic viscosity

3.4 Flash Point

From Figure 5, the results show that the pure coconut oil has higher flash point compare to the mineral oil. Sample D of pure coconut oil has the higher value of flash point which is 315°C. The lower value of flash point is obtained from sample A of mineral oil which is 152°C. The higher value of flash point can reduce the factor that the lead oil to flame when it is mixed with air. From the results, the pure coconut oil suitable to use as an insulating material of transformer.

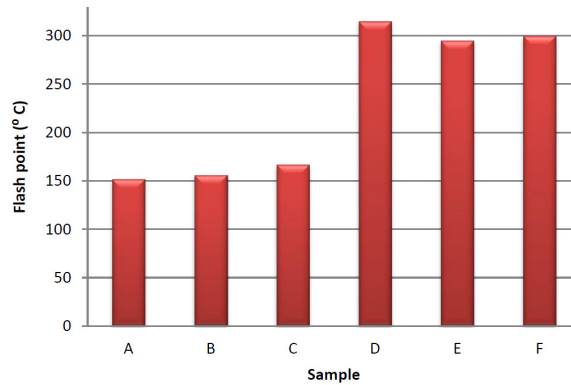


Figure 5: Graph for flash point

3.5 Water Content

From Figure 6, the higher value of water content is given by sample c of mineral oil compared the others samples which is 28 ppm. The lower value of the water content is given by sample F of pure coconut oil which is 12 ppm.

The oil of transformer should have the minimum value of water content because the insulating properties in oil will reduce due to increases in moisture contents. Water content amount are important in transformer because when the transformer cools down, it can lead to poor insulating properties and cause the fluid degradation. Therefore, the higher value of water content, the value of breakdown voltage will be reducing due the pleasuring void in the oil.

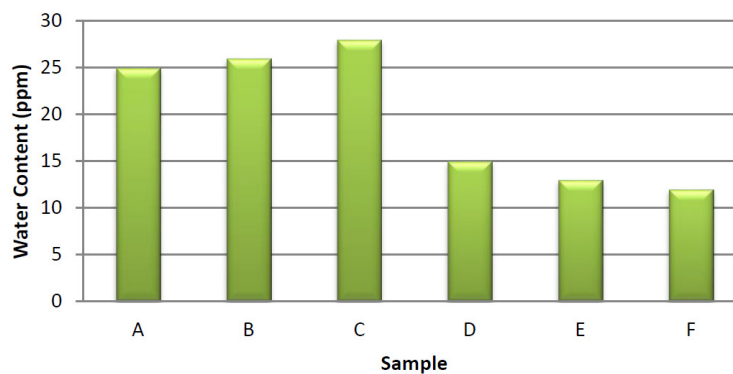


Figure 6: Graph for water content.

4.0 CONCLUSION

This study has been carried out to obtain the new insulating material as an insulation of transformer to replace the petroleum based mineral oil. The electrical and chemical properties have been studied and investigated in experiment work based on the standard. The results show that the pure coconut oil has a very good potential to be replacement existing oil which is petroleum based mineral oil. As the electrical properties, pure coconut oil is suitable to be used as an insulation of transformer because of the better properties. From the experiment carried out, the pure coconut oil shows the high breakdown voltage same as given by mineral oil. For the resistivity, pure coconut oil has ability to oppose the electric current flow in the transformer. As for the chemical properties, pure coconut oil has higher flash point compared to mineral oil, it can reduce the fire risk compared to the mineral oil.

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