Analysis of Chemical-Physical Properties and Breakdown Voltage of Rubber Seed Oil

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***Abstract*—This research is aimed to describe a new vegetable oil namely crude rubber seed oil as a substitute for mineral oil in oil insulating material. The vegetable oil is widely available in Indonesia but it is still untapped. Rubber seed oil is obtained from the rubber seed pressing process and the seed oil filtration process. In this research, the chemical-physics and electric properties of the crude rubber seed oil (CSO) are tested. As a comparator, mineral used is used and tested with the similar test. Chemical-physical properties of the crude rubber seed oil (CSO) and mineral oil are tested in the experiment. The results for CSO showed that the viscosity, acidity, water content and free fatty acids (FFA) are 31,05 mm2/s, 16,24 mg-KOH/gr, 6.100 ppm, 8,16% Oleat, respectively. for the CSO. For the mineral oil, test results showed that the viscosity, acidity, water content and free fatty acids (FFA) are 10.16 mm2/s, 8.02 mg-KOH/gr, 1.700 ppm and 7.29 % Naphthenic, respectively. The electric property tested in this research is breakdown voltage. The Breakdown voltage of crude rubber seed oil is 37.7 kV and 32 kV for mineral oil. This study found that the crude rubber seed oil (CSO) has a good prospect to develop into oil insulation.**

Keywords—Rubber seed oil, physical-chemical properties, breakdown voltage

I. INTRODUCTION

To date, mineral oil insulation is use to serve as the insulation liquid for many high voltage equipment such as transformer [1]. The mineral oil is proven to have good electrical and cooling properties. However, as the mineral oil is produced from mining material, the mineral oil is a non-renewable product and also not readily biodegradable. The mineral oil is also toxic due to polynuclear aromatic hydrocarbons content [2]. Thus, it can toxic the surrounding environment if the transformer is leaking, catch fire or explode.

Due to disadvantage above, many researchers conducted to find a better and safer oil insulation as a substitute to the mineral oil. The vegetable oil which is extracted from sun flower, olive, canola and soya bean has been applied for distribution transformer [1, 3, 4, 5, 6]. The vegetable oil, which can be classified as natural ester, is a bio-degradable material, thus environmentally friendly. Also, the vegetable oil has better electric properties such as higher dielectric strength and permittivity compare to the mineral oil [7]. Other electric property such as resistivity shows that the vegetable oil resistivity is almost as high as mineral oil resistivity [8]. The vegetable oil also has higher flash point and fire point which reduce the fire hazard possibilities. However, all the vegetable oils mention above are obtain from edible sources. So, there could be a conflict of interest with the food safety and availability. Thus, it is needed to find a non-edible vegetable oil that possible to develop into oil insulation.

In this research, discussed the possibility of rubber seed (*hevea brasiliensis* seed) as the source of the ester oil to be used as oil insulation. The rubber seed processed using mechanical pressing method to extract the crude rubber seed oil (CRSO). The CRSO is then filtered using filter paper to eliminate the presence of small debris that produced during the mechanical pressing process. Chemical-physical and electric properties of the RSO are tested in this research. For chemical-physical properties, the viscosity, water content, acidity and free fatty acid (FFA) are tested. The electric properties tested in this research is the breakdown voltage of the RSO. As a comparator, mineral oil is tested in similar means.

II. EXPERIMENT DETAILS

In this research discussed the chemical-physical and the electric properties of the rubber seed oil (RSO) and mineral oil. The chemical-physical test covers properties such as viscosity, water content, acidity and free fatty acid (FFA). The electrical properties test in the experiment is breakdown voltage of the rubber seed oil (RSO). In this research, mineral oil is used as a comparison to the RSO properties and tested in similar method.

A. Producing the rubber seed oil (RSO)

The rubber seed oil (RSO) is produced by mechanical pressing process. The mechanical pressing process is chosen as it is easy to carry out and the process did not alter the oil product as there are no heat or additive added in the process. The pressing machine used in this research is shown in Fig. 1.

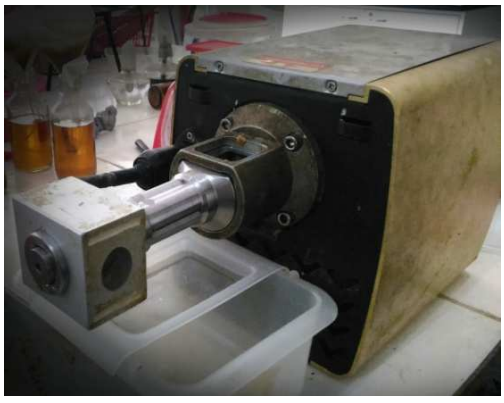

Fig. 1. Pressure machine Newest is uses to produce crude rubber seed oil (CRSO).

The rubber seed is pressed using pressing machine to produce crude rubber seed oil (CRSO). The crude oil then filtered to eliminate the small debris. The filtered oil then uses as the sample in the experiment. The typical crude rubber seed oil (CRSO) produced by the mechanical pressing process is shown in Fig 2.

Fig. 2. Crude rubber seed oil (CRSO)

B. Test Description

Viscosity test

Viscosity kinematic is tested based on ASTM-D445 standard. The equipment used on experiment is shown in Figure 3.

Fig. 3. Kinematic viscometer use in the reasearch

Water content

The water content is calculated using equation 1.

$$\%\, Water\ content\ = \frac{W_1 - W_3}{W_2} \text{ x } 100\% \qquad (1)$$

With :
W_1 = weight of oil sample + *beaker glass weight* before heated
W_2 = weight of oil sample
W_3 = weight of oil sample + *beaker glass weight* after heated

The CSO is heated up at 105^0C for 3 hours. Beforehand, the glass beaker is heated up also at 105^0C for 15 minutes to ensure the glass beaker is really dry. To heat up the CSO and glass beaker, a heater as shown in figure 4 is used.

Fig. 4. Jisico drying oven to heat up the oil sample

Acidity and free fatty acid (FFA)

Acidity and the FFA measurement were performed according to ASTM D 664 standard. Measurement test equipment is shown in figure 5.

Fig. 5. Acidity and FFA measurement

Breakdown voltage test

Breakdown test follows the ASTM 1612 standard. A Megger OTS80AF (Figure 6) is used to test the breakdown voltage of the rubber seed oil (RSO) and the mineral oil. The test needs 400 ml for each oil sample.

Fig. 6. Megger OTS 80AF used to test the RSO breakdown voltage

III. Experiment Results and Discussion

A. Chemical-physical Properties

Chemical-physical properties of the untreated rubber seed oil (RSO) and the mineral oil are shown in Table I. As mention before, the RSO obtain by using mechanical pressing method, without any further chemical treatment. Below discussed the chemical-physical properties value acquired in the experiment.

The test result for the viscosity value of the RSO is 31.05 mm2/s and for the mineral oil is 10.16 mm2/s both tested at temperature 400C. The IEEE C57.147 standard [9] noted that the vegetable oil should less than 50 mm2/s at temperature 40^0C and IEEE C57.106 [10] noted the viscosity of mineral oil should less than 12 mm2/s, also at temperature 40^0C. These results show that RSO produces by mechanical pressing is meets the standard value. Viscosity value is very affected the oil insulation quality. The lower the viscosity value the better the quality of the oil insulation. This is mainly due to the ability of the lower viscosity that easier to circulate inside the transformer tank thus provide better cooling mechanism.

The viscosity value of the untreated RSO has much higher value than the viscosity value of the mineral oil. This is one of the drawback of the vegetable oil when compare to mineral oil. Higher viscosity value will limit the cooling properties of the vegetable oil. Thus, until to date vegetable oil is used mainly for distribution transformer [1] as the cooling properties still adequate for distribution transformer. Nevertheless, the viscosity value of the RSO obtained in this research is still meets the IEEE C57.147 standard. Thus, the RSO has a high possibility to develop as oil insulation of the transformer.

The Acidity of the untreated RSO and the mineral oil are 16,24 mg-KOH/gr dan 8,02 mg-KOH/gr consecutively. The IEEE C57.147 standard requires the vegetable oil acidity should less than 0.06 mg-KOH/gr and less than 0,03 mg-KOH/gr for mineral oil according to IEEE C57.106 standard. The higher the acidity of oil insulation the more corrosive the material is. A corrosive oil insulation can damage the metal inside the transformer. If use for long period of time, the oil insulation might degrade the metal inside the transformer and might produces small metal particles. This will cause the transformer lifetime shorten. The acidity of the RSO in this research is much above the acidity standard level. This mean, the untreated RSO cannot use as it is as oil insulation as it is. Further process is needed to reduce the acidity to meet the standard value. However, the mineral oil use in the experiment also has value above the standard value. Perhaps it is caused by the mineral oil using as comparator also not treated yet and also has been stored for a quite long period of time.

The water content in the untreated RSO is 6.100 ppm and for the mineral oil is 1.700 ppm. Both of these results show higher value than the allowed number according to the IEC 60422 standard [11]. The standard IEC 60422 noted that for a level voltage 70 kV, the water content should not more than 10 ppm. Thus, for untreated RSO further process such as heating is need to reduce the amount of water content. This process can be arranged in quite easy way. The water content of the mineral oil also shows very high value compare to the allowed standard value. This is probably due to the mineral oil use in the experiment not only untreated ones but also has been kept in storage in quite long period of time.

TABLE I. Chemical-physical properties of the rubber seed oil (RSO) and untreated mineral oil

Test Parameter	CSO	Mineral Oil	Test Standard	Standard Value	
				CSO	*Mineral oil*
Viscosity (mm^2/s at 40°C)	31,05	10,16	ASTM D 445	(IEEE C57.147) ≤ 50	(IEEE C57.106) ≤ 12
Acidity (mg-KOH/gr)	16,24	8,02	ASTM D 664	(IEEE C57.147) ≤ 0,06	(IEEE C157.106) ≤ 0,03
Water content (ppm)	6.100	71.700	ASTM D 2709	(IEC 60422) ≤ 10	(IEC 60422) ≤ 10
Free fatty acid - FFA (%)	8,16 (Oleat)	7,29 (Naphthenic)	ASTM D 664	-	-

TABLE II. The breakdown voltage test result of RSO and mineral oil

No.	RSO Breakdown Voltage (kV)	Mineral oil Breakdown Voltage (kV)
1	35	31.4
2	44	34.6
3	41.6	26.8
4	37	31
5	36.6	36.2
6	32.1	32
Average	37.7	32.0

The free fatty acids (FFA) value for both RSO and mineral oil are 8,16 % (Oleat type) and 7,29 % (Naphthenic type) consecutively. High FFA value shows that both oil have possibilities to ignite oxidation process when the oil is use. Thus, the RSO still needs a further process to eliminate the presence of the FFA. Perhaps chemical process is needed to reduce the RSO. This will conduct in the future experiment, where the RCO will be treated using chemical process. The mineral oil also shows high FFA value. This might because the oil has been kept for a long period.

B. Breakdown Voltage

Breakdown voltage test is conducted using a Megger OTS80AF. The megger has standard operation that will take 6 times test automatically for each sample. The breakdown voltage is calculated as the average of the breakdown voltage of the 6 test results. For the experiment, 400 ml oil sample is used for each RSO and mineral oil. The oil is placed into the test cup (Figure 7). The oil temperature during test is around $40\ ^0$C. The average of the breakdown voltage after test are 37.7 kV and 32.0 kV for both RSO and mineral oil respectively.

Fig. 7. The breakdown voltage test cup

The RSO breakdown voltage shows higher value than the breakdown voltage value of the mineral oil. This shows the RSO is a very good candidate to develop into oil insulation. Also, tough the RSO is untreated, the breakdown voltage as high as 38 kV is already above the breakdown voltage value of the "New mineral insulating oil as received from supplier" as noted in IEEE C57.106-2006 standard. Future study is to treatment the RSO to obtain better physical and electrical properties. Chemical treatment, such as esterification perhaps could increases the physical and electrical properties of the RSO.

IV. Conclusion

The non-edible rubber seed oil (RSO) shows a good possibility as the source vegetable oil and might be able to developed into oil insulation. The test results of the chemical properties of the untreated rubber seed oil (RSO) in this research showed that the viscosity, acidity, water content and free fatty acids (FFA) are 31,05 mm2/s, 16,24 mg-KOH/gr, 6.100 ppm, 8,16% Oleat, respectively. As comparator, tested mineral oil showed that the viscosity, acidity, water content and free fatty acids (FFA) are 10.16 mm2/s, 8.02 mg-KOH/gr, 1.700 ppm and 7.29 % Naphthenic, respectively.

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