Comparison of Physical Characteristics between Vegetable and Mineral Oils

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Abstract This paper presents physical characteristics of vegetable oils which are commercial products. The vegetable oils under consideration in this work are comprised of sunflower oil and rice bran oil. The characteristics of the vegetable oils are found by testing and they are compared with that of the mineral oil according to IEC and ASTM standard. The results show that physical characteristics of the two vegetable oil types, it is found that the vegetable oils under test have satisfactory characteristics comparable with the mineral oil. Therefore, it has high possibility that those vegetable oils can be used for electrical insulation of electrical machines.

1 INTRODUCTION

The coming of global oil crisis also affects the price of the mineral oil which is refined from petroleum oil. Mineral oil is well known as an insulating materials and arc quenching medium in electrical power equipment [1, 2]. Liquid dielectrics are mainly employed as impregnates in high voltage equipment. The petroleum based oils are commonly used in the transformers are electric insulation and a coolant for heat dissipation. These materials can be mineral oils, synthetic hydrocarbon, silicone and ester. All of these liquid materials have been proved as an efficient medium in the transformer insulating system. However due to environment concern, there have been plenty of attempts to develop products from the nature, in particle vegetables, in order to be the electrical insulating materials [2-6] In addition, it has been found that the distribution transformer with vegetable oils has benefits in the longer useful life and lower failure rates due to overload condition [7].

Especially in Thailand, we have a little resource of natural gas and almost no oil resource but we have a lot of agriculture products. Therefore, the study of oil produced from vegetable for replacing the mineral oil is one of the best solutions in Thailand. The main propose of the vegetable oils in Thailand is for cooking, and some applications in bio-fuels.

In the past of research [8], it was presented dielectric characteristics of vegetable oils. Two types of vegetable oils are sunflower oil and rice bran oil to be a good trend to study of other properties.

This paper provides a comparison of physical characteristics between commercial vegetable oils and insulated mineral oil.

2 VEGETABLE OILS

Vegetable oils are the natural products. The vegetable oils are mostly produced by the fatty acid in vegetable seed [1-7]. In Thailand, there are two types of popular oils, which are sunflower oil and rice bran oil. These oils contain unsaturated fatty acid. The samples of these two commercial vegetable oils are show in figure 1.

(a) (b)

Figure 1: Sample of vegetable oils used in experiments, (a) the sunflower oil and b) rice bran oil).

3. EXPERIMENTS AND TEST RESULTS

Experiments in this paper are carried out according to international standards and can be separated in two parts. The first part is experiments for evaluation of physical characteristics and the second part is an aged test by simulated PD.

3.1 Physical Characteristics

3.1.1 AC Dielectric Breakdown Voltage Test

The purpose of the AC dielectric breakdown voltage test is to determine the breakdown voltage of the insulating material. The AC dielectric breakdown voltage test of the two vegetable oils samples were performed according to IEC 156 [9]. The automatic tester for liquid insulating material was employed. The equipments are shown in Figure 2 and 3.

Figure 2: Dielectric breakdown voltage test unit

Figure 3: Electrodes and test cell

The results shown in Figure 4 are the dielectric breakdown voltage of the two oil samples compared with a mineral oil. The breakdown voltages were recorded automatically from the tester unit. It is found that the sunflower oil gives the highest AC withstand voltage more than others.

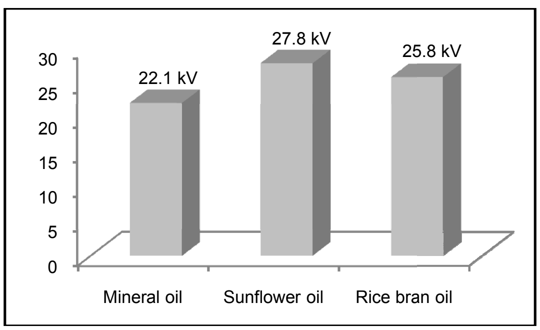

Figure 4: AC dielectric breakdown voltages of the vegetable oils compared with of the insulated mineral oil.

3.1.2 Dielectric loss test (Tanδ)

Dielectric loss factor or dielectric dissipation loss factor is an important indicator for the quality of the electrical insulation since the factor represents the level of loss in the insulation. For liquid insulating materials, the dielectric loss factor is also relevant to the contaminants quantity such as water in the insulation [1, 2]. It is well know that the dielectric loss factor is measured in the term of tan delta. The dielectric loss tests of the two vegetables oil samples were performed according to ASTM D924-03A [10]. During the tests, the temperature of the oils was controlled at 30 ^{o}c and 100 ^{o}c. The equipments used in the experiments are shown in Figure 5. Figure 6 shows the test results of the tan delta of the oils. The dielectric loss of the insulating materials is caused by the presence on conductive current, and regarded to be proportional with the tan delta value. Hence, the sunflower oil has the lowest dielectric loss among the vegetable oils used in the experiments. It is found that the sunflower oil has the same value of tan delta as that of mineral oil.

Figure 5: Equipments for loss factor test.

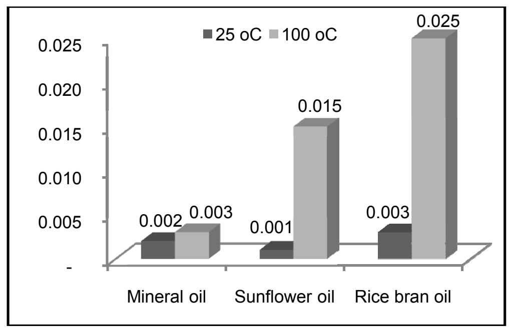

Figure 6: Tan delta result.

3.1.3 Permittivity measurement

The result shown in Figure 7 is the relative permittivity of the vegetable oils. All vegetable oils have similar relative permittivity.

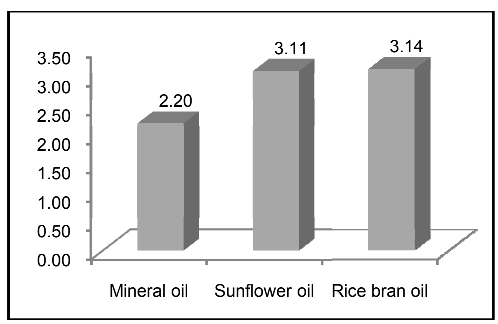

Figure 7: Relative permittivity of the vegetable oils compared with of the insulated mineral oil.

3.1.4 Impulse Voltage Withstand Tests

During the operation of the transformer, there are possibilities for the transformer to be under the electric stress caused by transient over-voltages, which are generated by switching operations of switchgears and lightning. Therefore, the electrical insulation material in the transformer, must withstand the over voltages at the suggested level. The overvoltage withstand of electrical power equipments are tested by subjecting impulse voltages. The impulse voltage withstands tests of the two vegetable oil samples were performed according to ASTM D3300-00 [11]. The impulse voltages with negative polarity were applied to the test cell, and the breakdown voltage was recorded. The testing arrangement and a test cell are shown in Figure 8 and 9

Figure 8: Impulse voltage test arrangement

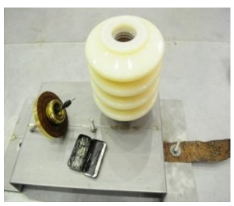

Figure 9: Test cell for oil insulating materials

The results of the breakdown voltages shown in Figure 10 are the average values, and it is found that the polarities of the impulse waveforms have an effect on the breakdown voltage of the vegetable oils. The sun flower oil has the highest impulse voltage withstand. Comparing with the standard impulse breakdown voltage of the transformer oil, the vegetable oils reveal inferior properties in withstanding voltage. It should be noted that all experiments were conducted with the surrounding temperatures of 27^{o}c-30^{o}c, the humidity of 73%-77% and the air pressure of 763 mm.Hg.

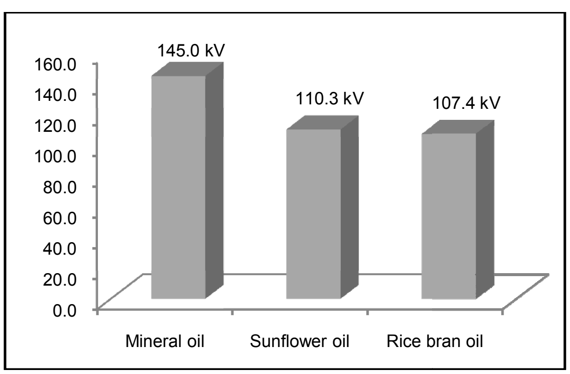

Figure 10: Impulse breakdown voltage of the oils under test.

3.1.5 Acid Number Test

The purpose of the acid number test is to determine the acid number of the liquid insulating material. High acidities accelerate the degradation of the paper insulation and causes corrosion of the steel tanks. The acid number of the two vegetable oil samples was measured by titration with a KOH solution in according to ASTM D974-04 [12] (Molarity, M = 0.03). The automatic tester for liquid insulating material was employed. The equipments are show in Figure 11.

Figure 11: Acid number test unit

The results shown in Figure 12 are the acid number of two types of oils compared with a mineral oil. The acid number was recorded automatically from the tester unit. It is found that the vegetable oils are gives the acid number less than the mineral oil.

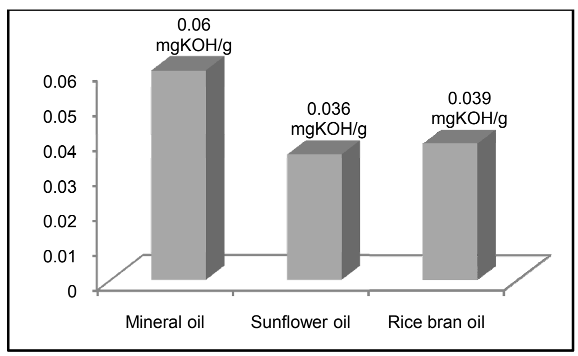

Figure 12: Acid numbers of the oils under test.

3.1.6 Interfacial Tension Test (IFT)

Interfacial tension test (IFT) is a tool to evaluate the property of liquid insulation. The interfacial tension of the liquid insulation should be keep low for preventing sludge on the soild insulation. The interfacial tension tests of the two vegetable oil samples were performed according to ASTM D971 [13]. The automatic tester for liquid insulating material was employed. The equipments are show in Figure 13.

Figure 13: Interfacial tension test unit

The results shown in Figure 14 are the interfacial tension of two types of oils compared with a mineral oil. The interfacial tension was recorded from the tester unit. It is found that the rice bran oil has the lowest interfacial tension and the both of vegetable oils have the interfacial tension less than the mineral oil.

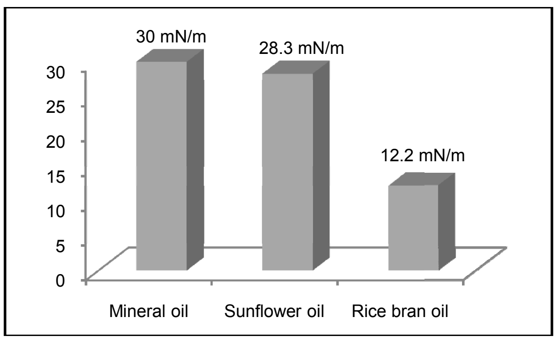

Figure 14: Interfacial tension test results

3.1.7 Moisture Content

The moisture content is used to determine the water in the liquid insulating material. Water may be introduced to the oil by leaking gaskets, poor handling techniques or from the product of natural insulating paper and oil degradation. Water is a polar liquid having a high permittivity or dielectric constant. It is therefore attracted to areas of strong electric fields. Thus, the internal moisture is not uniformly distributed, but in fact potentially concentrating in the most dangerous parts of the system. If oil is oxidized to any extent, any water coming into the transformer will partially be absorbed into the oil decay products [14]. The moisture content tests of the two vegetable oil samples were performed according to ASTM D1533 [15]. The moisture content of an oil samples is measured using an automatic Karl Fischer Coulometric Titration. The equipments are shown in Figure 15.

Figure 15: Moisture content test unit

The results shown in Figure 16 are the moisture content of two samples compared with a mineral oil. The moisture content was recorded from the tester unit. It is found that the sunflower oil and rice bran oil gives the highest moisture content more than the mineral oil.

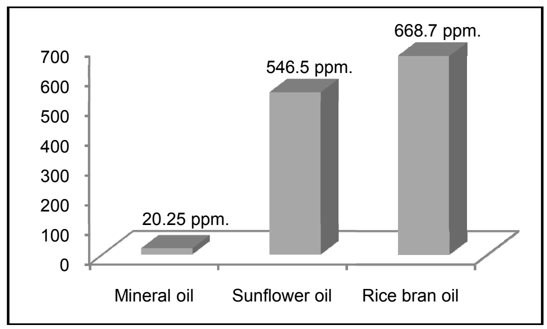

Figure 16: Moisture content test results

3.2 Aged Test by Simulated PD

3.2.1 The preliminary test

The preliminary test is an AC breakdown voltage test with varied temperature of the two oil samples from 20 to 90 degree Celsius. The test cell is according to IEC 156 [9] but the gap distance varied from 2.5 to 10 mm. The test arrangement and test cell in the tests are shown in Figure 16.

Figure 17: Breakdown voltage test arrangement

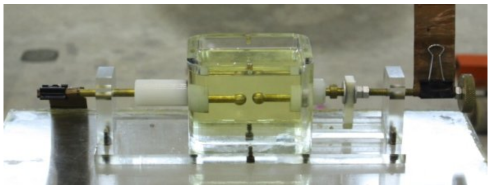

Figure 18: Test cell for breakdown voltage test

The results of breakdown voltage under gap spacing and temperature differences of the mineral oil, sunflower oil and rice bran oil are shown in Figure 19, 20 and 21. The breakdown voltages are increased when gap spacing and temperature are increased.

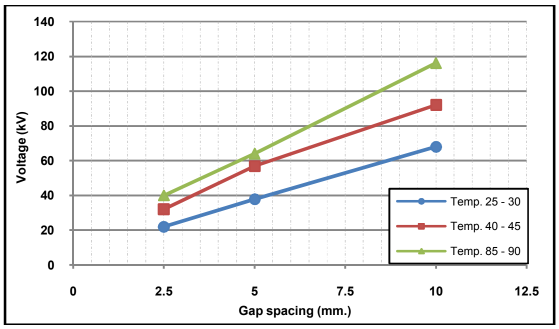

Figure 19: The result of breakdown voltage under gap spacing and temperature differences of mineral oil

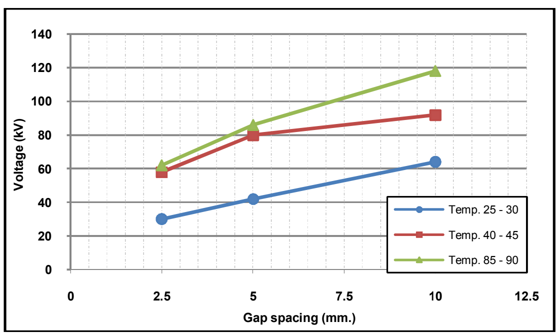

Figure 20: The result of breakdown voltage under gap spacing and temperature differences of mineral oil

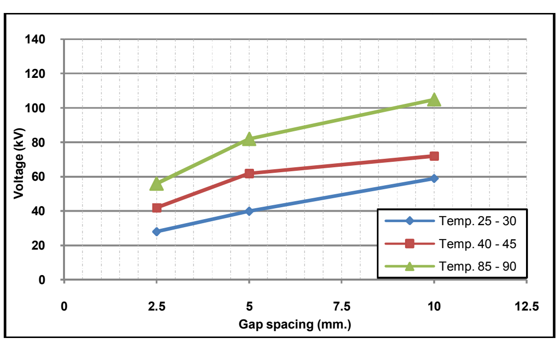

Figure 21: The result of breakdown voltage under gap spacing and temperature differences of mineral oil

3.2.2 Partial Discharge Test

The simulated partial discharges are generated by applying to the rod-plane gap enclosed by the test cell filled by the oil, which is either sunflower oil or rice bran oil. The PD measurement is carried out according to the IEC standard [16].The applied voltage is fixed at 20 kV and the gap distance is set to be 2 cm. The time periods of the tests are 10 to 30 minutes. The test arrangement and the test cell used in the experiments are shown in Figure 22. The examples of the results of simulated partial discharge in vegetable oil samples are shown in figure 23 to 25.

Figure 22: Partial discharge test arrangement

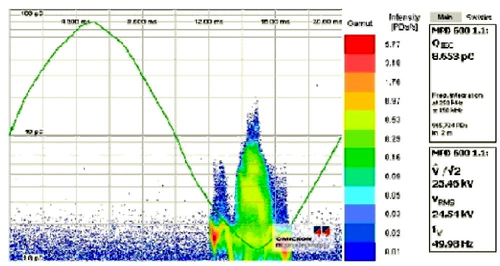

Figure 23: Simulated partial discharge in mineral oil for 30 minutes.

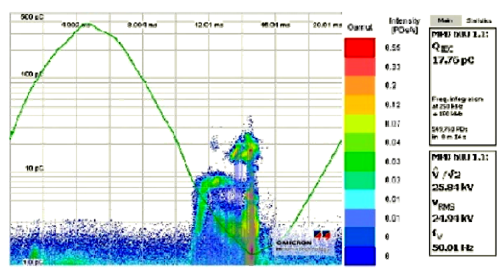

Figure 24: Simulated partial discharge in sunflower oil for 30 minutes.

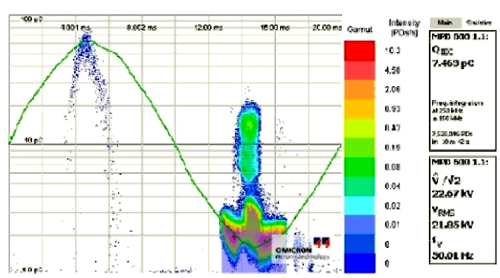

Figure 25: Simulated partial discharge in rice bran oil for 30 minutes.

The results shown in Figure 26 are the breakdown voltage of the two vegetable oil samples and mineral oil aged by simulated PD with various time periods of the experiments. The vegetable oil under test show better performance than that of mineral oil when aged test by simulated partial discharge is performed.

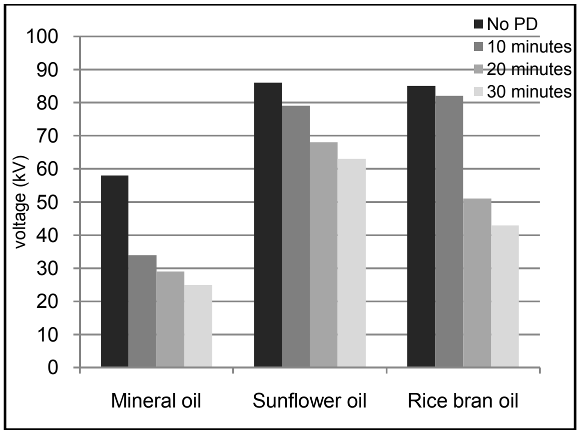

Figure 26: Breakdown voltages of the oils after the aged test**.**

4. CONCLUTIONS

The physical characteristics of the two types of vegetable oils, rice bran and sunflower, are investigated in this paper. It is found that the two vegetable oils have satisfactory characteristics comparable with the mineral oil. Therefore, it has high possibility that those vegetable oils can be used for electrical insulation of electrical machines.

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