Preliminary results on the development of monoester type insulating oil from coconut oil

by Abdul Rajab

Submission date: 17-Sep-2019 09:47AM (UTC+0800)

Submission ID: 1174122990

File name: Preliminery_Result.pdf (956.01K)

Word count: 2308

Character count: 11980

IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Preliminary results on the development of monoester type insulating oil from coconut oil

To cite this article: A Rajab *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **602** 012035

View the article online for updates and enhancements.

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 103.212.43.184 on 07/09/2019 at 03:13

IOP Conf. Series: Materials Science and Engineering **602** (2019) 012035 doi:10.1088/1757-899X/602/1/012035

Preliminary results on the development of monoester type insulating oil from coconut oil

A Rajab, F E Putra, J S Ramadhani, M S I Silitonga, R Kurniawan, K Qibran, M Latif, and M I Hamid

Electrical Engineering, Universitas Andalas, Padang, Indonesia

E-mail: a.rajab@eng.unand.ac.id

Abstract. Vegetable oils, both in tri-ester and monoester forms have been attractive alternative substitutes for replacing mineral oil as the insulating liquid used in power transformer. An effort to develop a monoester type insulating oil derived from coconut oil has been conducted, and the preliminary results of the development are reported in this paper. Five different samples were prepared from methyl ester of coconut oil based on their melting point. The important properties of oil samples such as viscosity, water content, acidity, and density were tested, and are evaluated based on the standard specification of natural ester used for the transformer. Another fundamental property, i.e., oxidation stability was also tested and is evaluated by comparing the corresponding result of mineral oil. It is found that oil needs further treatment before being able to be used as insulating oil.

1. Introduction

Mineral oil derived from crude petroleum oil has been used as insulating oil in various electrical apparatus such as transformer since the 19th century. A mineral oil immersed transformer is found to be more efficient and smaller in size compared to the transformer of dry type [1]. The mineral oil was still the favorite choice until an environmental consideration in selecting an insulating oil is emerging during the last two decades [2]. The biodegradability rate of mineral oil is low. Therefore, the oil is considered to be not environmental friendly. The environmental issue motivates researchers and practicers search for an alternative liquid to be used for insulation and coolant purpose. Another motivation is the fact that the mineral oil is the nonrenewable product, since the crude petroleum oil, the source of the mineral oil, will eventually run out in the future [3].

Ester groups appear to be the promoting source of the insulating oil which is friendly to the environment. Synthetic ester was the first ester group oils used for that purpose. The first implementation of the oil was in a distribution transformer in 1978 and then followed by its application in a 230 kV power transformer in 2003 [4]. The biodegradability rate of oil is about 97%, much higher than that of the mineral oil which is only 30% [3, 5]. Natural ester from vegetable oil was also introduced as the insulating liquid, and it has been implemented in a distribution transformer since 1990 [6]. The biodegradability rate of the natural ester is as high as that of synthetic ester [5]. The natural esters also have advantages in a higher fire point and nontoxicity. The higher fire point means that the oil has a lower fire risk than that of mineral oil.

Nevertheless, the natural esters have a high viscosity make them not well suited for applications in cold climate and transformers relying on the natural cooling system [7]. Also, the natural esters are

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

generally susceptible to oxidation due to the natural existence unsaturated double bond (C=C) in their hydrocarbon chains. It is recommended to have natural esters containing a less number of C=C for better oxidation stability. Unfortunately, the viscosity of the later mentioned oils is high [2]. A low viscosity oil is required as other functions the insulating oil is to dissipate heat created in the transformer during the operation.

An effort to develop a low viscosity insulating oil from the natural esters have been made [7, 8]. It was conducted by modifying the chemical structure of natural ester from tri-ester to monoester [8], or by mixing the monoester and tri-ester [7]. The monoesters derived from triesters contain a mixture of saturated an unsaturated monoesters. Separation of the saturated monoester from the mixture is needed to have a monoester with high oxidation stability. In our previous work [9], the separation was performed using the distillation technique utilizing the difference in boiling point of each mixture components. The results show that the dissipation factor, the viscosity and the breakdown voltage of the monoester oils are acceptable, whereas the oxidation stability of the oil is low. It was suspected that the lower oxidation stability was due to damage of the oil's molecules caused by heating during the distillation process. In the current study, the separation was conducted using the fractionation technique utilizing the difference in melting point of each mixture components of monoester. Each fractionated samples was tested for the viscosity, the oxidation stability, the water content, the acidity, and the density. The results were compared with the corresponding values of the specification standard (ASTM D-6871) or mineral oil.

2. Experiment

2.1. Sample Preparation

The oil used in the experiment was methyl ester derived from coconut oil. Five kinds of samples were prepared based on the melting point of each component of the methyl ester. At the first step, the methyl ester of about 5 liters was solidified in a refrigerator set to the temperature of -8 °C. After the entire oil was solidified, the oils were then taken out from the refrigerator to have the liquified oil back. The first 1 liter of the liquefied oil was considered to be the sample S1, the next 1 liter was designated as S2, and so no up to the S5 for the last 1-liter liquified oil. Therefore, there five samples having different melting points.

2.2. Procedure

The standard procedure for testing an as-received new natural ester used for transformer insulation and the required value of each oil properties are listed in Table 1. For instance, the testing procedure for viscosity follows the standard procedure ASTM D445, and the required value for the viscosity at the temperature of 40 °C is not more than 50 cSt.

Table 1. As-Received New natural ester Property Requirements for transformer use

Property	Limit	Test Method
Fire Point, min, °C	300	D 92
Pour Point, max, °C	-10	D 97
Relative Density, 15 °C/15 °C, max	0.96	D 1298
Viscosity (40 °C), max, cSt	50	D 445
Breakdown voltage, min, kV	35	D 1816
Dissipation factor at 60 Hz, 25 °C, max, %	0,2	D 924
Acid number, max, mg KOH/g	0,06	974
Water content, max, mg/kg	200	D 1533

3. Results and Analysis

IOP Conf. Series: Materials Science and Engineering **602** (2019) 012035 doi:10.1088/1757-899X/602/1/012035

The main challenges in the application of natural ester as insulating oil are the viscosity and the oxidation stability. Hence, both properties are the main focus of the investigation reported in this paper. In original form, triglyceride, the natural ester typically has higher viscosity and lower oxidation stability. The viscosity problem was overcome by using the monoester type in the experiment, instead of the tri-ester type, whereas the oxidation problem was handled by performing fractionation. Also, other important properties were also evaluated.

3.1. Viscosity

The viscosity of all tested samples and the required value from the ASTM D 6871 standard are shown in Figure 1. It can be seen from Figure 1 that the viscosity of all tested samples is less than that specified by the standard. This is the expected results since the lower viscosity means, the easier for the oil to transfer heat that can lead to better cooling efficiency. Coolant is another function of oil inside the transformer, in addition to being the isolation.

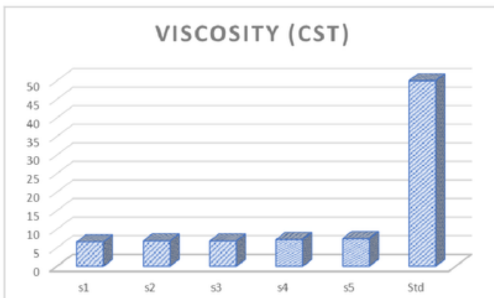

Figure 1. The viscosity of all tested samples and the standard

3.2. Oxidation Stability

As can be seen from Table 1, the oxidation stability is not specified in the ASTM D 6871 standard. However, the oxidation stability is one of the very important aspects in determining the long-term performance of an insulating oil in a transformer. In this regards, the oxidation stability of all samples was evaluated by measure their peroxide value. The higher peroxide value means the higher amount of oil sample oxidized during the test. Figure 2 shows the peroxide value of all oil samples, as well as mineral oil. It can be seen from Figure 2 that the peroxide value of all monoester samples is much higher than that of mineral oil. This means that the monoester oil needs further treatment to improve the oxidation stability.

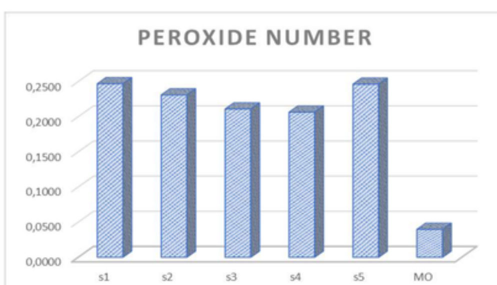

Figure 2. Peroxide number of all tested samples and the standard

3.3. Water Content

IOP Conf. Series: Materials Science and Engineering **602** (2019) 012035 doi:10.1088/1757-899X/602/1/012035

The electrical properties of the insulating oil are very sensitive to the water. For instance, the breakdown voltage decreases drastically when the relative water content reaches 30 % and 10 % for clean and unclean insulating oils, respectively [4]. If the water solubility of monoester is about 1100 ppm [10], then the relative water contents of 30% and 10% correspond to the absolute water contents of 300 ppm and 100 ppm, respectively.

The water content of all tested samples and the required value by the standard are depicted in Figure 3. It is clear from Figure 3 that the water content of all tested samples is significantly higher than that specified by the standard. The water content removal should be performed to get the monoester based insulting oil.

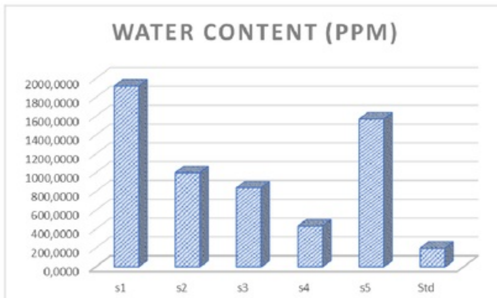

Figure 3. The water content of all tested samples and the standard

3.4. Acid Number

The acid number is another important properties to determine the quality of the insulating oil. For an unused ester, it indicates the existence of free fatty acids in the oil. These acids belong to the group of high molecular weight acids, and their presence with the acid number larger than 9 mg KOH/g can affect the breakdown voltage of the ester oil [11]. The acid number of all tested samples is much higher than the ASTM D 6871 standard specification suggesting further treatment before the oil could be used as insulating oil for the transformer.

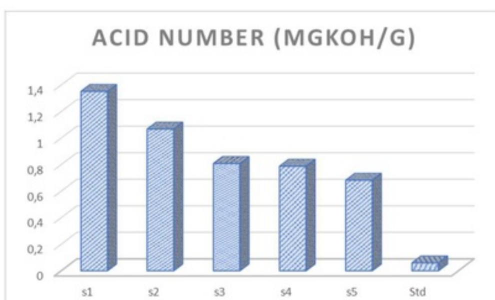

Figure 4. The acid number of all tested samples and the standard

3.5. Relative Density

The relative density required for as-received natural ester-based insulating oil is equal or less than 0,96, as mentioned in Table 1. The measurement results of the density are depicted in Figure 5. It is shown in Figure 5 that the density of all oil sample is well below the value specified by the standard.

Relative density is not too significant in determining the quality of the insulating oil. Instead, it is pertinent to determine the suitability for use in specific applications.

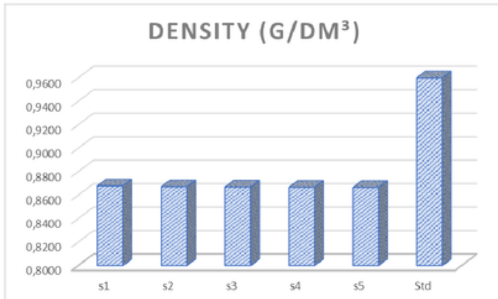

Figure 5. The density of all tested samples and the standard

4. Conclusion

The development of a low viscosity insulating oil from monoester is ongoing progress. The current results show that the viscosity and the density of the monoester derived from coconut oil comply well with the standard specification of as-received natural ester used for an oil-filled transformer, ASTM D 6871. However, further treatments are required to improve the oxidation stability and to reduce the water content of the oil, as well as the acid number.

References

[1] A Rajab, A Pawawoi, A Sulaeman, D Mujahidin 2014 *Study Penggunaan Metil Ester Minyak Sawit Sebagai Minyak Isolasi Peralatan Listrik*, Jurnal Nasional Teknik Elektro, 3(1), pp. 1-4.

[2] A Rajab, M Tsuchie, M Kozako, M Hikita, T Suzuki 2016 PD Properties and Gases Generated by Palm Fatty Acids Esters (PFAE) Oil, *IEEE International Conference on Dielectric*.

[3] C C Claiborne, E J Walsh and T V Oommen 1999 An Agriculturally Based Biodegradable Dielectric Fluid in *IEEE/PES T&D Conference*, New Orleans.

[4] CIGRE W G A2.35 2010 Experience in Service with New Insulating Liquid CIGRE.

[5] C P McShane, G A Gauger and G Luksich 1999 Fire Resistant Natural Ester Dielectric Fluid and Novel Insulation System for Its Use, *IEEE/PES Transmission, and Distribution Conference.*

[6] C P McShane 2001 Relative Properties of the New Combustion-Resistant Vegetable-Oil-Based Dielectric Coolants for Distribution and Power Transformers, *IEEE Trans. on Industry Application*, 37, pp. 1132-1139.

[7] C P McShane 2002 Vegetable Oil Based Dielectric Coolants, IEEE Industry Applications Magazine, pp. 34-41.

[8] I Bertrand, P Lauzevis 2013 Development of A Low Viscosity Insulating Liquid Based on Natural Ester for Distribution Transformers, *22nd International Conference on Electricity Distribution*.

[9] N Aziz 2012 Ageing Assessment of Insulation Paper with Consideration of in-service Ageing and Natural Ester Application, *Ph.D. thesis*, University of Manchester.

[10] T Kanoh, et al. 2008 Analyses of Electro-Chemical Characteristics of Palm Fatty Acid Esters as Insulating Oil, *IEEE International Conference on Dielectric Liquids*.

[11] T V Oommen, C C Claiborne and J T Mullen 1997 Biodegradable Electrical Insulation Fluids, Electrical Insulating Conference, Chicago.

Preliminary results on the development of monoester type insulating oil from coconut oil

ORIGINALITY REPORT

15%	13%	9%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	A Rajab, H Gumilang, M Tsuchie, M Kozako, M Hikita, T Suzuki. "Study on static electrification of the PFAE-mineral oil mixture", IOP Conference Series: Materials Science and Engineering, 2019 Publication	9%
2	journal.uad.ac.id Internet Source	6%

Exclude quotes	Off	Exclude matches	< 3%
Exclude bibliography	On		