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Utilization of Palm Oil Wastewater as Raw Material Alternative for Transformer Insulation Oil

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Abstract

Insulator oil is one of important parts in transformer, in a form of a liquid, functioned as insulating and cooling media. The insulator oil made of mineral oils used in transformer potentially causes environmental problems, especially when an explosion occur inside the transformer which may cause oil spill or water contamination. Here, we study the used of Palm Oil Mill Effluent (POME) as the raw material for insulation oil. In this work, POME was extracted, distilled, measured the acid value followed by esterification and transesterification processes to obtain the insulation oil. The viscosity, flash point, acid value, and breakdown voltage of the insulation oil was measured. In the esterification process, HCl catalyst was added with a ratio of 1.5% to degrade the acid value of the oil, while in the transesterification process, NaOH or KOH catalysts were added with a ratio of 1.5 and 3%. The result for KOH catalyst is as follows, viscosity were 2.09 and 2.32 cSt, the flash point were 166 and 170^{o}C, and the acid value were 0.5 mg KOH/g after the addition of 1.5 and 3% catalyst respectively, while the breakdown voltage was 55 kV after the addition of 1.5% KOH catalyst. NaOH catalyst shows result: viscosity were 5.34 and 5.02 cSt, the flash point were 178 and 183^{o}C, and the acid value were 0.5 mg KOH/g after the addition of 1.5 and 3% catalyst, respectively, while the breakdown voltage was 46 kV after the addition of 1.5% KOH catalyst.

Keywords: POME, Insulation Oil, Transformer, KOH, NaOH

Abstrak (Indonesian)

Minyak isolator adalah cairan yang penting dalam transformator yang berfungsi sebagai pengaman dan pendingin. Minyak isolator yang terbuat dari minyak mineral yang digunakan pada transformator berpotensi menyebabkan masalah lingkungan, terutama ketika terjadi ledakan di dalam transformator yang menyebabkan tumpahnya minyak atau terkontaminasinya air. Penelitian ini menggunakan *Palm Mill Oil Effluent* (POME) sebagai bahan baku minyak isolator yang diekstraksi, didistilasi, diukur nilai asamnya, kemudian dilanjutkan dengan proses esterifikasi dan transesterifikasi untuk mendapatkan minyak isolator. Nilai viskositas, titik nyala, nilai asam, dan tegangan tembus minyak isolator kemudian diukur. Dalam proses esterifikasi, katalis HCl ditambahkan dengan rasio 1,5% untuk menurunkan angka asam minyak. Sedangkan pada proses transesterifikasi, katalis NaOH maupun KOH ditambahkan dengan rasio 1,5 dan 3%. Hasil untuk katalis KOH menunjukkan viskositas 2,09 dan 2,32 cSt, titik nyala 166 dan 170^{o}C, dan angka nilai asam 0,5 mgr KOH/gr setelah penambahan berturut-turut, katalis sebesar 1,5 dan 3%, sedangkan tegangan tembus diperoleh 55 kV setelah penambahan katalis KOH dengan rasio 1,5%. Untuk penggunaan katalis NaOH, didapatkan viskositas 5,34 dan 5,02 cSt, titik nyala 178 dan 183^{o}C, dan angka asama dalah 0,5 mgr KOH/gr setelah penambahan berturut-turut katalis sebesar 1,5 dan 3%, sedangkan tegangan tembus diperoleh 46 kV setelah ditambahkan katalis KOH dengan rasio 1,5%.

Kata Kunci: POME, Minyak Isolator, Transformator, KOH, NaOH

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INTRODUCTION

Power transformer is an electrical power equipment that serves to channel power/electric power from high voltage to low voltage or vice versa. Based on the operating voltage, transformers can be divided into 500/150 kV and 150/70 kV transformers commonly known as Interbus Transformer (IBT). The 150/20 kV and 70/20 kV transformers are called distribution transformers. The transformer neutral point is set according to the need of the security/protection system [1].

Transformer oil is functioned as an insulation and a cooling medium between wire coils or iron core with cooling fins. An electrical equipment must have electrical insulation and must have thermal insulation, electrical insulation serves to separate the parts of the equipment that have a potential difference while thermal insulation functions to absorb heat that occurs due to the use of continuous and too high loads. If the heat generated on the transformer is not channeled or not cooled and exceeds the maximum temperature, there will be a part of the equipment that will be damaged. To overcome this, the core and coil of the transformer are dipped into a liquid insulation, which functions as a cooling and insulation media. So the transformer oil should have a high breakdown voltage, low dielectric leakage factor, low viscosity, high flash point, low density, chemical stability and good gas absorption, low acid value, low sulfur corrosion, light yellow appearance, low pour point, low water content, and low relativity [2].

The insulation oils that are often used are known as mineral insulator oil, synthetic insulator oil, and organic insulator oil [3][4][5]. Mineral oils has been used as transformer insulation oil for more than 150 years in many industries, including transportation and power plant [6]. The usage of mineral insulator oil widely nowadays is flammable because it has the inability to withstand the elevated sparks and voltage surge [7]. Meanwhile, the synthetic insulator oil is an oil that has a chemical process that is expected to have better characteristics to be used in the electricity system. This type of oil is more beneficial because it is not flammable and is not easily oxidized. But it is toxic [4]. Aside of mineral oil, there are also plant-based insulator oils called vegetable oil (organic oil) which are being studied massively. One of the efforts that can be done to reduce the use of mineral oil is to find alternatives raw material for making liquid insulator. Vegetable oils are widely studied to be an alternative liquid insulator, namely virgin coconut oil (VCO), crude palm oil (CPO), castor oil, corn oil and others. The advantages of non-toxic vegetable oil, as the waste products due to reactions in the form of CO_2 and water; are biodegradable, have a high flash point, better thermal characteristics and renewability [8]. In line with the environment awareness improvement, research into renewable, environmentally friendly insulator oils has developed [7].

The waste produced from the palm oil industries are in the form of solid and liquid waste. The liquid wastewater known as Palm Oil Mill Effluent (POME). However, untreated POME, which directly discharged into the environment, would cause water pollution. Some of the pollution would be sediment, slowly decomposed, caused turbidity, odor, and damaged the aquatic ecosystems. In addition, air pollution caused by methane gas (CH_4) and carbon dioxide (CO_2) formed from the evaporation process of open ponds heated by the sunlight has the potential to damage the environment and the ozone layers [9]. In Indonesia, palm oil production on the first quarter of 2019 amounted to 1,906,000 tons and produced 4,765,000 m^3 of POME [10]. That's why the POME have to treat well. The purpose of this study was to utilize POME as the raw material for making liquid insulator.

Before becoming to a bio insulator oil, the oil produced from POME come into the biodiesel oil stage because there are several conditions that must be met by the bio insulator oil, namely low viscosity, high flash point, and pour point [11]. In this study Palm Oil Mill Effluent (POME) was used as the alternative raw material for insulation oil. The POME was extracted, distilled, measured the acid value, then continued by esterification and transesterification processes in order to make the insulation oil.

Esterification is the conversion stage from free fatty acids to esters. Esterification reacting the fatty oil with alcohol. Suitable catalysts for esterification process are substances with strong acidic characteristics, hence, sulfuric acid, organic sulfonic acid or strong acid cation exchange resins are commonly chosen catalysts in industrial practice [12]. The esterification process aims to lower the levels of acidity, and also fat, utilizing an acid catalyst, e.g., HCl or H_2SO_4 [13]. While transesterification is a chemical reaction in fats or oils with alcohol with the help of a catalyst to produce esters or glycerol. Some types of alcohol that can be used for the transesterification process include methanol, ethanol, propanol, and amyl alcohol, but methanol is used more because it is cheaper and easier to use. The stages of transesterification process are as follows: glycerol separation, biodiesel wash, and biodiesel drying [11]. The process of transesterification involved the use of potassium hydroxide (KOH) catalyst to enhance the yield of biodiesel [14].

The catalysts in the biodiesel oil production process above (esterification or transesterification) are materials that function to accelerate reactions by reducing activation energy and not changing the equilibrium of the reaction, and are very specific [15]. As for commercial scale biodiesel processing, the homogeneous alkali catalysts was utilized, which is more commonly used in transesterification reactions because they produce high methyl esters and at fast times. The commonly used catalyst concentration is 0.5-4% of the weight of oil [16]. Hence the catalysts choice are very important in the esterification and transesterification processes as the biodiesel production stage in order to find the biodiesel which the meet the characteristics of the insulation oil.

In this study, the insulation oil was made from the POME through the esterification and transesterification processes. The effect of alkaline catalyst type and concentration in the transesterification process on the insulation oil characteristics were also studied

MATERIALS AND METHODS

Materials

N-Hexane was used as the solvent in extraction process. Methanol was used for the esterification and transesterification process. Chloroform, Ethanol, dry Potassium Hydrogen Phthalate and Phenolphthalein indicators were used to analyze acidic values. Chloride acid was used as catalyst for the esterification process, then Potassium Hydroxide and Sodium Hydroxide were used as alkaline catalyst for the transesterification process. All the chemicals were obtained from Merck.

Methods

In this study, the POME was extracted by using n-hexane solvent, and then distilled to separate the solvent. The acid value of the oil get from destilation proses was measured. In the extraction process, the POME and n-Hexane solvent was prepared by a ratio of 3:2 with the total volume of 300 ml. To separate the solvent from oil, distillation process was done by set the heater to the temperature of 75-80°C. Evaporated n-Hexane were collected into an Erlenmeyer.

In the esterification process, the oil was mixed with methanol and HCl of 2.5% of was used as the catalyst. While in the transesterification process, the alkaline catalyst of KOH and NaOH were used. The concentration percentage was varied of 1.5% and 3% for each alkaline catalyst. The method for extraction, esterification, and transesterification processes were explained elsewhere by Nuryanti et.al [17]. The density, viscosity, flash point, acid value, and breakdown voltage of the insulation oil produced from the stage of biodiesel processes, were measured.

RESULTS AND DISCUSSION

The oil obtained from POME extraction as an alternative raw material in making transformer insulation oil, then goes through the esterification and transesterification processes. The density, viscosity, flash point, acid number, and breakdown voltage of the oil obtained from these stages are then measured. The characteristics of transformer oil insulation made from POME are presented in Table 1.

Table 1. The POME insulation oil characteristics

Oil Properties	Unit	Standard	KOH Concentration		NaOH Concentration	
			1.50%	3%	1.50%	3%
Viscosity	cSt	< 25	2.09	2.32	5.34	5.02
Flash Point	°C	> 144	166	170	178	183
Acid Value	mg KOH/g	> 0.06	0.5	0.5	0.5	0.5
Breakdown Voltage	kV	> 30	55	NA	46	NA

The Effect of Alkaline Catalysts on the Insulation Oil Viscosity

Effect of alkaline catalysts on insulation oil viscosity was shown in Figure 1. By using NaOH and KOH with a ratio of 1.5% and 3%, consecutively the viscosity value of the insulation oil were 5.34 and 5.02 cSt when using NaOH catalysts, while the value when using KOH catalysts were 2.09 and 2.32 cSt. The KOH catalyst give a lower insulation oil viscosity. This is caused by using this catalyst, the conversion achieved is greater, as report elsewhere; so that the oil produced is closer to the character of the insulation oil.

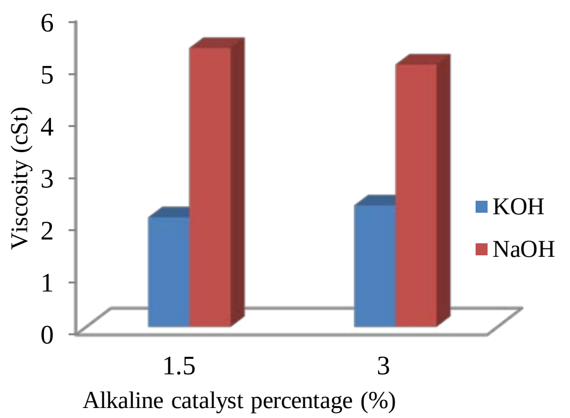

Figure 1. The Effect of Alkaline Catalysts on the Insulation Oil Viscosity

The insulation oil has fulfilled the standard of SPLN 49-1:1982, because the standard oil viscosity is <25 cSt. The effect of catalyst percentage is not significant.

The Effect of Alkaline Catalysts on the Insulation Oil Flash Point

Figure 2 illustrate the effect of alkaline catalysts on insulation oil flash point. By using NaOH and KOH catalyst with a ratio of 1.5% and 3%, the flash point value of the insulation oil were 178°C and 183°C when using NaOH catalysts, while the value were 166°C and 170°C when using KOH catalyst.

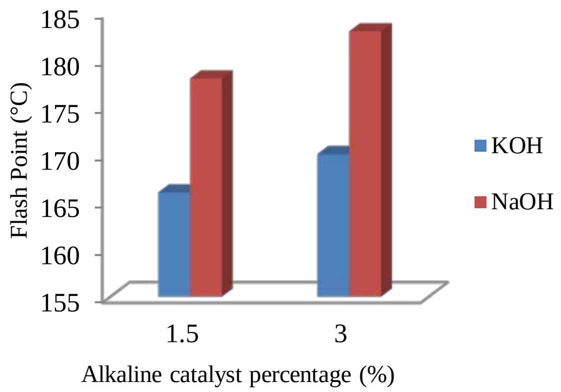

Figure 2. The Effect of Alkaline Catalysts on the Insulation Oil Flash Point

These value has met the standards of insulation oil since the flash point standard is >144°C. The higher the flash point value is, the better the quality will be. In this case the NaOH catalyst gives better results than the KOH catalyst. Also the higher the percentage of catalyst used, the higher the flash point of the oil has.

The Effect of Alkaline Catalysts on the Insulation Oil Acid Number

By using NaOH and KOH with a ratio of 1.5 and 3%, the acid number of the insulation oil were both 0.5 mg KOH/g. This value had not met the 49-1:1982 SPLN standard, which is <0.40. If the acid number of the insulating oil is high, the oil quality is getting worse; in contrast, if the acid number of the insulator oil becomes lower, the oil quality will be better. Effect of alkaline catalysts on the insulation oil acid number can be seen in Figure 3. As shown in the figure, the alkaline catalysts type and the percentage of the catalysts are not effect to the acid number of the insulation oil.

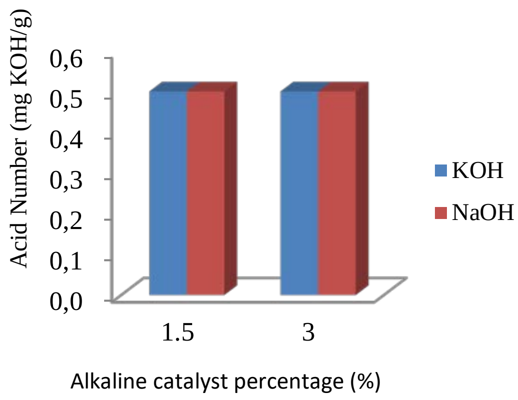

Figure 3. The Effect of Alkaline Catalysts on the Insulation Oil Acid Number

The high value of acids number in the insulation oil content may cause corrosion in the transformer, so the transformer will be damaged quickly. Therefore, the acid number of the insulation oil should be very small so the transformer has a long duration life. So it is important to reduce the acid number so this insulation oil can be applied.

The Effect of Alkaline Catalysts on the Insulation Oil Breakdown Voltage

Figure 4 demonstrates the effect of alkaline catalyst on the insulation oil breakdown voltage. In measuring the breakdown voltage, the insulation oil used which is produced from the transesterification process using 1.5% of alkaline catalyst. Because the use of 3% alkaline catalyst produces very little insulation oil and tends to freeze up during the transesterification process.

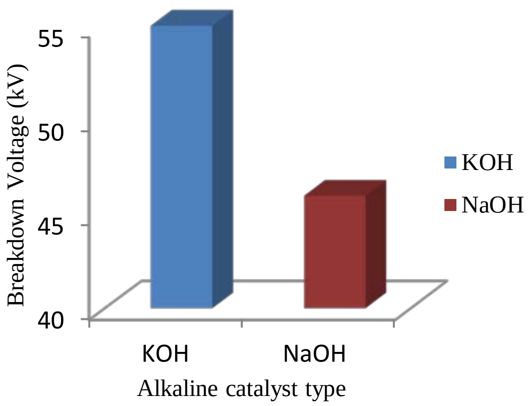

Figure 4. The Effect of Alkaline Catalysts on the Insulation Oil Breakdown Voltage

The obtained breakdown voltage value of the insulation oil by using KOH and NaOH catalysts were 55 kV and 46 kV, respectively. The breakdown voltage value of the two different catalysts had exceeded the standard breakdown voltage values of >30 kV. This means both of alkaline catalysts are good to use as insulation oil. These results are better than other research by using Reutealis Trisperma oil which the breakdown voltage of 17.55 was reported [7].

CONCLUSION

In this study, the oil from extracted POME was utilize as a raw material alternative for making insulation oil through esterification and transesterification processes. The alkaline catalysts of KOH and NaOH were used in transesterification process. The alkaline catalyst type effect the viscosity, flashpoint, and breakdown voltage character of the insulation oil produced. But the alkaline catalyst type was not effect to the acid number of the insulation oil. The quality of the insulation oil obtained by using KOH catalyst is better compared to the one using NaOH, which have a lower viscosity and higher breakdown voltage value. However, the higher flash point were reached by using NaOH catalyst.

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