Investigation of Dissolved Decay Products in Various Transformer Oil using UV-Vis Spectrophotometry

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ABSTRACT – The performance and lifespan of transformer is mainly depends on its insulation condition. In this paper, the dissolved decay product (DDP) in mineral insulating oil (MI) and natural ester insulating oil (NEI) during ageing process are examined using UV-Visible Spectrometer (UV-Vis). The UV-Vis spectral response of each samples are taken at 1000 and 1500 hours of accelerated ageing process. It was found that DDP of oil samples at 1500 hours higher compare to oil samples at 1000 hours.

1. INTRODUCTION

Power transformer plays the key role in preserving efficiency and maintaining the reliability of electricity transmission in any distribution network. Lifespan of a power transformer depends on its insulation system which consists of liquid and solid insulation. Liquid insulation either mineral or natural ester based also acts as coolant for power transformer's winding due to oil ability to dissipate heat by convection [1-2].

Conventionally, mineral insulating oil (MI) is used as liquid insulation in power transformer. However, due to some environmental issues, natural ester insulating oil (NEI) is proposed to replace MI as transformer insulation. NEIs are made from numerous ester types and properties which lead to a different ageing and deterioration effects. Usually, oil is deteriorated due to ageing, acid, sludge, moisture and dust particles causes by chemical and physical properties reactions [3-4].

According to ASTM D6802 [5], decay products such as sludge and dust particles which dissolved in mineral insulating oil can be determine by using spectrophotometry. Therefore, this paper investigates the dissolved decay products (DDP) of three different insulating oils; mineral, palm based, and rapeseed based, under thermal ageing condition by using UV-Vis spectrophotometry. UV-Vis spectrophotometry is one of the methods which provide a platform for visual identification of the age of oil. It can be used for the aging analysis of insulation oil with respect to the contaminant present in it.

2. EXPERIMENTAL SETUP

Three different types of transformer insulating oil are used in this experiment; mineral oil, palm-based oil and rapeseed-based oil. A laboratory accelerated thermal aging to simulate the transformer ageing process is conducted in accordance to the method proposed by S. Tenbohlen [6] as in Figure 1. In this method, the kraft paper (KP) weighing used is by ratio 1:10 of oil weight. New oil of each insulating types is placed in the vacuum oven at temperature at 130 ℃ for 1000 hours and 1500 hours. Next, DDP for each samples are measured in accordance to ASTM D6802 [5] using laboratory UV-Vis spectrophotometry.

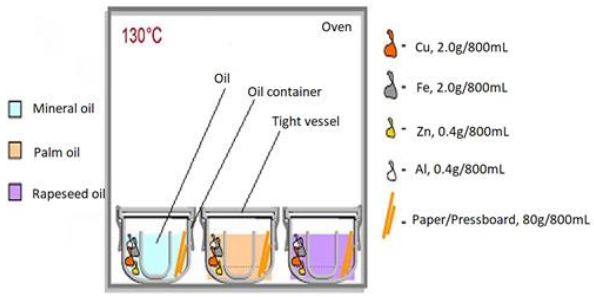

Figure 1 Accelerated thermal aging setup.

3. RESULTS AND ANALYSIS

For DDP test, the wavelength range chosen for this study is between 360 nm to 600 nm as per suggested in ASTM D6802 [6]. The absorbance amount is referred to the values of UV-Vis light been absorbed by the dissolved decay product in the oil. High value of absorbance indicates high amount of DDP. The DDP's relative content of oil samples is determined by integrating the area under an absorbance versus wavelength curves. While, equation (1) is used to calculate the percentage increment of dissolved decay product, PI_{DDP} for oil samples.

$$PI_{DDP} = \frac{DDP_{new} - DDP_{old}}{DDP_{old}} \, x \, 100 \qquad (1)$$

Figure 2 shows the correlation between UV-Vis absorbance and wavelength of mineral oil for two different ageing hours. The initial relative DDP for mineral oil (sample 0 hours) was 19.59. After 1000 hours of accelerated ageing process, DDP was increased to 369.06, and keep increasing up to 580.73 after 1500 hours. It also been notice that the oil with higher DDP will have a longer wavelength compared to the oil with lower DDP.

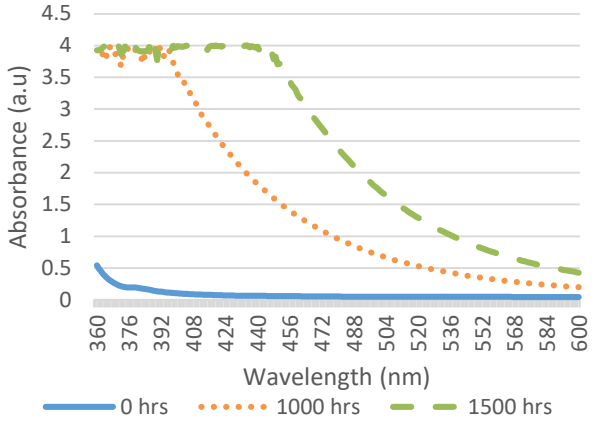

Figure 2 Correlation between uv-vis absorbance and wavelength (nm) for mineral oil.

The same pattern can be observed for palm-based oil as shown in Figure 3. Although the trend is same between mineral and palm-based oil, however the increment rate of DDP for both insulating oils are different. Palm-based oil has a higher DDP increment rate compared to mineral oil for the first 1000 hours. After that, the DDP increment rate for palm-based become smaller compared to mineral oil as shown in Table 1.

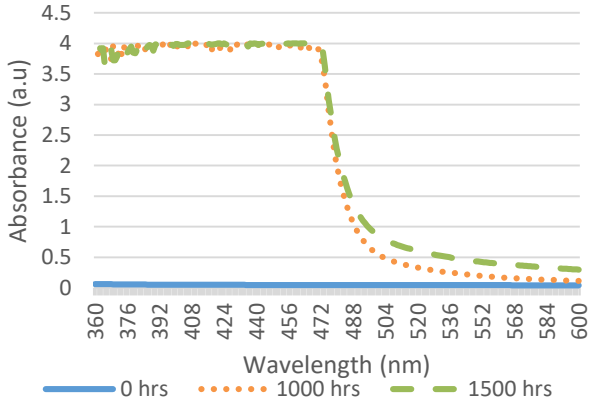

Figure 3 Correlation between uv-vis absorbance and wavelength (nm) for palm-based oil.

Table 1 Percentage increment dissolve decay product from wavelength (360-600) nm.

Duration aging (hrs)	Mineral oil	Palm-based oil	Rapeseed-based oil
1000	1783.74%	4472.06%	1427.86%
1500	57.35%	5.76%	-18.42%

On the other hand, rapeseed-based oil shows a different trend of DDP amount compared with previous aforementioned oil types as shown in Figure 4. For rapeseed-based oil, the DDP amount in oil increased significantly for the first 1000 hours. However, this amount was decrease from 535.07 to 436.51 after additional 500 hours of ageing period. These also been notice by looking at the wavelength peak absorbance which shifts from 430 nm (sample 1000 hour) to 390 nm (sample 1500 hour).

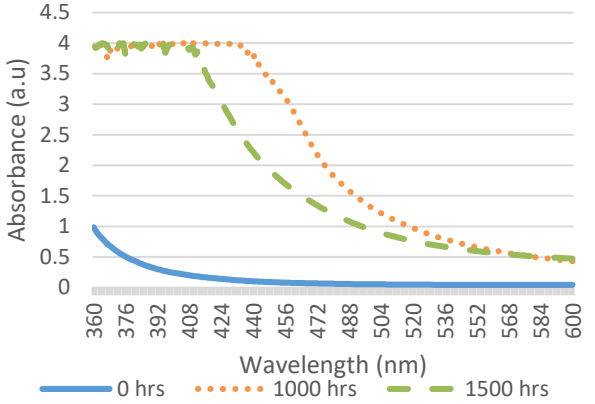

Figure 4 Correlation between uv-vis absorbance and wavelength (nm) for rapeseed-based oil.

4. CONCLUSIONS

This paper investigates the development of DDP in oil based on UV-Vis spectral response for three different oil types; mineral, palm-based and rapeseed-based oils. Result shows that each oil-based produce difference correlation between DDP and it's oil spectral response. It also been notice that different types of oil shows a different relative amount of DDP at the beginning, hence considering the area changing rate is more appropriate to reflect the DDP development in oil instead of the area values.

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