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Overview

Editors:

- Nur Syazreen Ahmad, Junita Mohamad-Saleh, Jiashen Teh

- Presents the proceedings of the 12th International Conference on Robotics, Vision, & Power Applications
- Covers various areas of robotics, signal processing, communication technology and energy systems
- Highlights state-of-art technologies that can be adopted by the relevant industries

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About this book

This book presents selected papers from the Proceedings of the International Conference 12th International Conference on Robotics, Vision, Signal Processing, and Power Applications ROVISP 2023, held in Penang, Malaysia, covering topic areas divided into the following tracks: (1) Robotics, Control, Mechatronics, and Automation; (2) Vision, Image and Signal Processing; (3) Telecommunication Systems and Applications; (4) Electronic Design and Applications; (5) Electrical Power, Energy, and Industrial Applications. Its content highlights state-of-the-art technologies adopted by the relevant industries which appeal to researchers and industrial practitioners working in the field.

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Vision, Image and Signal Processing

Exploring the Impact of Accelerated Thermal Aging on POME-Based MWCNT Nanofluid

Sharifah Masniah Wan Masra, Yanuar Zulardiansyah Arief, Siti Kudnie Sahari, Ernieza Musa, Andrew Ragai Henry Rigit, and Md. Rezaur Rahman

Abstract This study aims to investigate the effects of accelerated thermal aging on modified refined, bleached, and deodorized (RBDPO) olein. Through a transesterification process, the RBDPO olein is converted into palm oil methyl ester (POME), which acts as the base fluid in the presence of conductive multi-walled carbon nanotube (MWCNT) at various concentrations. The accelerated aging is conducted at a temperature of 130 °C for 1000 h. Fourier transform infrared (FTIR) analysis reveals that the chemical composition of the aged nanofluids remains unchanged. The AC breakdown voltages of the aged nanofluids decrease as a result of the accelerated thermal aging over 1000 h, but they remain higher than those of the fresh POME.

Keywords Thermal aging · Palm oil methyl ester · Multi-walled carbon nanotube

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1 Introduction

A significant shift in research interest towards the exploration of biodegradable and renewable alternatives in the field of nanofluid research has arisen recently. Numerous studies have explored replacing mineral oils with modified vegetable oils [1–4]. Transformer insulating liquids are subjected to electrical, thermal, and chemical stresses, causing them to gradually deteriorate [5]. Aging is the mechanism responsible for resulting in gradual and irreversible changes in the properties of transformer oil [5]. An enhanced understanding of the properties changes of aged nanofluids subjected to accelerated aging conditions is thus important to quantify the variations of nanofluid properties at various concentrations and aging durations at a specified operating temperature. Therefore, the objective of this study is to expand the scope of research by modifying refined, bleached, and deodorized palm oil (RBDPO) olein into methyl ester and incorporating nanoparticles to examine the aging mechanism's effect on the oil samples. The question focuses on whether the modified nanofluids retain their dielectric strength after thermal aging.

2 Experiment

2.1 Materials

This project utilizes several key materials, including RBDPO olein, methanol sourced from Merck, potassium hydroxide (KOH) obtained from J. T. Baker, conducting multi-walled carbon nanotube (MWCNT) nanoparticles, and hexadecyltrimethylammonium bromide (CTAB) surfactant manufactured by Sigma-Alrich.

2.2 Transesterification Reaction

The investigated methyl ester in this study was synthesized through a transesterification reaction involving RBDPO olein, methanol, and KOH as a catalyst. The reaction was conducted with a molar ratio of 6:1 (methanol:oil) at a temperature of 60 °C, while continuously stirring the mixture for 60 min. After cooling the mixture to room temperature, it was transferred to a separatory funnel and left to settle for 24 h. As a result of transesterification, the mixture separated into two distinct phases: glycerol and methyl ester. The bottom phase, consisting of crude glycerol and KOH, was discarded. The top layer, which contained fatty acid methyl ester (FAME), underwent a water-washing process to remove excess KOH. The remaining impurities were eliminated by heating and stirring the mixture at 60 °C for 30 min using a magnetic stirrer. Subsequently, the resulting FAME obtained from the transesterification of

RBDPO olein was designated as palm oil methyl ester (POME) and utilized as the base fluid for preparing the nanofluids.

2.3 Nanofluids Preparation

The nanofluids were prepared using a two-step method. The first step involved the preparation of the dried nanoparticles, specifically MWCNT, which were pre-heated in an oven to eliminate any moisture. In the second step, the nanofluids were prepared by dispersing the dried MWCNT nanoparticles into the POME base fluids through chemical and mechanical treatments. To initiate the dispersion process, an appropriate amount of the CTAB surfactant as investigated in [2], was added to 1000 ml pre-dried POME and stirred for 30 min. Then, the MWCNT nanoparticles were dispersed into the POME to achieve various concentrations required for the nanofluid samples. The considered doping concentrations of MWCNT NPs were 0.01, 0.02, 0.05, and 0.10 g/L. To ensure homogeneity and minimize the risk of agglomeration and sedimentation, the prepared nanofluid samples underwent ultrasonication at a temperature of 50 °C for 2 h. This ultrasonication process further aided in achieving well-dispersed and homogeneous nanofluids [6].

2.4 Mechanism of Nanofluids Aging

The prepared nanofluid samples were exposed to accelerated thermal aging in an oven under closed aging conditions, with the temperature at 130 °C. The analysis was performed at four different aging durations: 0, 250, 500, and 1000 h. The AC breakdown voltage (AC BDV) measurement was used to assess the aging behavior of the nanofluids. The qualitative degradation of the breakdown voltage of the modified nanofluids in response to accelerated thermal aging is studied.

3 Characterization and Measurements

3.1 FTIR Spectra Analysis

In this study, the characterization of the pure POME and the aged nanofluids was performed using a Thermo Scientific Fourier Transform Infrared (FTIR) spectrophotometer to gain insights into the aging behavior of the POME blended with MWCNT nanoparticles. The FTIR spectra were recorded with the absorbance bands of the nanofluids over a range of wavenumbers from 4000 to 600 cm^{-1}. The FTIR conditions were set with 32 scans and a resolution of 4.

3.2 AC BDV Measurement

The AC BDV measurement of the nanofluids was conducted using an HZJQ-1B transformer oil BDV tester with IEC 60156 compliance standard testing. The electrodes of brass hemispherical-shaped with a diameter of 12.5 mm and at a fixed distance of 2.5 mm were used in the testing. The voltage was automatically increased at a rate of 2 kV/s until breakdown occurred. To ensure consistency, all measurements were performed with constant stirring of the oil samples. For each nanofluid sample, we conducted six sets of six consecutive AC BDV measurements and then calculated the average value.

4 Findings and Analysis

4.1 FTIR Analysis

The FTIR study aimed to assess any changes in functional groups resulting from aging. Figure 1 displays the comparative FTIR analysis of nanofluids aged at different concentrations and durations. Visual examination of the spectra indicated that aging did not significantly alter the spectra. This finding aligns with the findings of a previous investigation conducted by [7], which examined various esters and nanoparticles. Notably, a distinct, sharp peak was observed at the absorbance wavenumber 1741 cm^{-1}, indicating the stretching vibration of C=O and confirming the presence of ester. Peaks at wavenumbers 2922 and 2852 cm^{-1} suggested the presence of carboxylic acids [8].

4.2 Average of AC BDV

A total of 36 AC BDV measurements were conducted on both fresh and aged nanofluids at different aging durations. The average AC BDV values are presented in Fig. 2. The results indicate that the BDV of the aged nanofluids after 1000 h is higher compared to the fresh nanofluids. The incorporation of MWCNT nanoparticles in the POME base fluids has a positive impact on all doping concentrations, with a concentration of 0.10 g/L nanoparticles showing the highest BDV, as depicted in Fig. 2. Overall, the analysis reveals that the dielectric strength of the nanofluids increases after 250 h of aging but subsequently decreases with prolonged aging. However, it has been observed that the AC BDVs of the aged nanofluids are always superior to the pure POME, irrespective of aging duration.

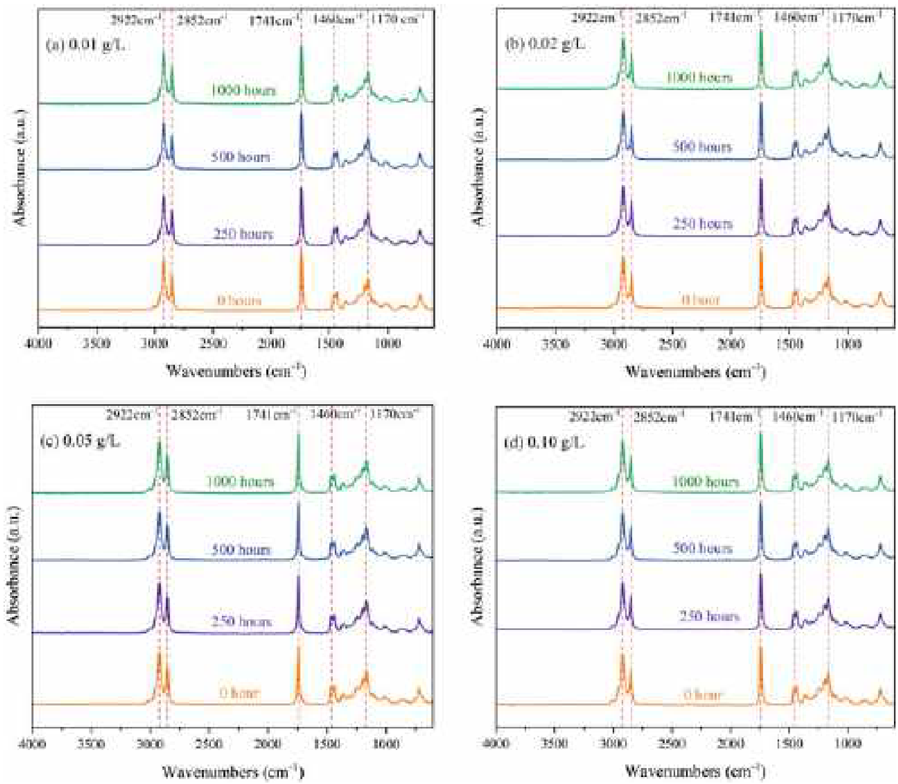

Fig. 1 FTIR spectra of fresh and aged nanofluids at various concentrations

4.3 Statistical Analysis

The Weibull distribution plots at a 95% confidence interval of nanofluids for 0- and 1000-h aging periods are shown in Fig. 3. The star, square, triangle, and circle plots indicate the doping concentrations of 0.01, 0.02, 0.05, and 0.10 g/L MWCNT nanoparticles, respectively. Table 1 shows the scale (α) and shape (β) parameters of the Weibull distributions for 1000-h-aged NFs. Then, the agreement of the BDV data following the Weibull distribution was determined by the Anderson–Darling (AD) goodness-of-fit test [9]. The ρ-value was determined and compared to the 0.05 significance level. Table 1 also summarizes the results of the AD test. The results indicate that the AC BDV at low concentrations (0.01, 0.02, and 0.05 g/L) obeys the Weibull distribution. The Weibull fit lines as shown in Fig. 3b were used to evaluate the AC BDV at 1%, 10%, and 50% probability failure, and the results are tabulated in Table 2. For $U_{10\%}$ and $U_{50\%}$, the AC BDV was optimal with concentrations at 0.02 g/L, which gave improvements of 5.2% and 50.6% higher than the pure POME.

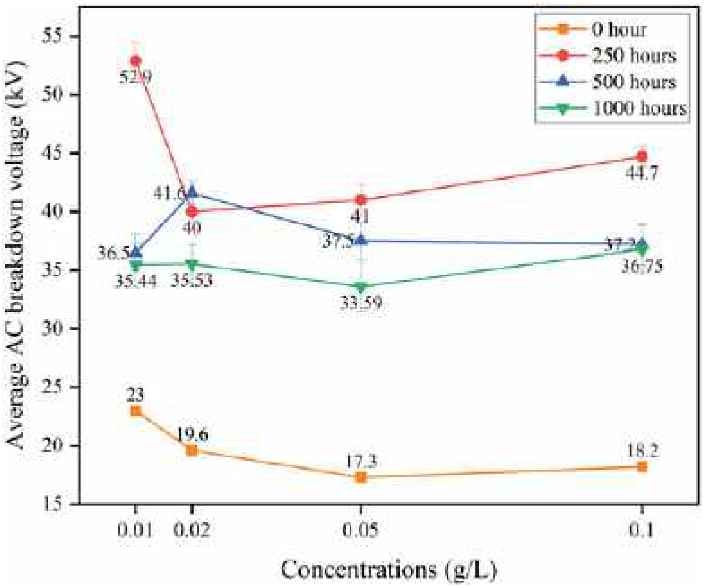

Fig. 2 Average AC BDV of fresh and aged nanofluids

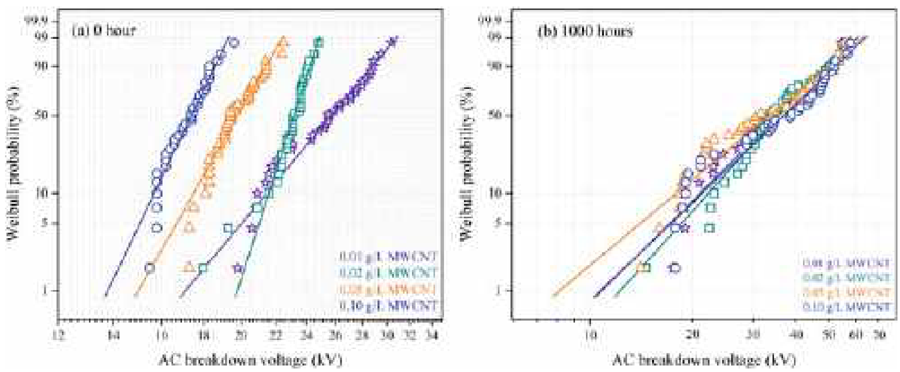

Fig. 3 Weibull distribution plots of AC BDV for **a** 0, and **b** 1000 h

Table 1 Scale, shape parameters, and AD Goodness-of-fit test for 1000-h-aged NFs

Oil samples	α (Scale)	β (Shape)	ρ-value	Decision
Pure POME	24.2	15.8	$\geq$ 0.25	Accepted
0.01 g/L NF	39.5	3.6	0.240	Accepted
0.02 g/L NF	39.2	3.9	0.122	Accepted
0.05 g/L NF	37.8	3.0	0.054	Accepted
0.10 g/L NF	41.1	3.4	0.024	Rejected

Table 2 AC BDV at 1%, 10%, and 50% probability levels

Oil samples	$U_{1\%}$		$U_{10\%}$		$U_{50\%}$	
	AC BDV (kV)	Increment (%)	AC BDV (kV)	Increment (%)	AC BDV (kV)	Increment (%)
Pure POME	18.1	–	21.1	–	23.7	–
0.01 g/L NF	10.8	– 40.3	21.0	– 0.5	35.6	50.0
0.02 g/L NF	12.3	– 32.0	22.2	5.2	35.7	50.6
0.05 g/L NF	8.3	– 54.1	17.9	– 15.2	33.5	41.4

5 Conclusions

By modifying RBDPO olein through a transesterification process and blending it with conducting MWCNT nanoparticles, this study aims to explore its potential use as an alternative insulating liquid in transformers. Two aspects of thermal aging in nanofluids were studied: FTIR spectra analysis and AC BDV measurements. The key findings can be summarized as follows: (a) The chemical structure of aged nanofluids remained unchanged, as observed in the FTIR spectra; (b) The dielectric strength of the aged nanofluids are always superior to pure POME, irrespective of aging duration; and (c) The statistical analysis demonstrated that the low concentrations of 1000-h-aged NFs results obey the Weibull distribution.

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