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INVESTIGATION ON THE POSITIVE AND NEGATIVE LIGHTNING BREAKDOWN VOLTAGES OF REFINED BLEACHED AND DEODORIZED PALM OIL OLEIN UNDER THE PRESENCE OF COPPER (II) OXIDE NANOPARTICLE

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ABSTRACT

In this paper, a study on the lightning impulse breakdown voltages of Refined, Bleached and Deodorized Palm Oil (RBDPO) Olein and Mineral Oil (MO) with the present of the semi conductive nanoparticle, Copper (II) Oxide (CuO) under non-uniform field is carried out. The lightning breakdown test was carried out based on needle-sphere electrodes configuration at gap distances of 25 mm. Rising voltage testing method was used and both positive and negative voltage polarities were considered. CuO was added into RBDPO and MO percentages volume concentrations of 0.001%, 0.025% and 0.050% without presence of surfactant. It is found that there are slight improvements on the lightning breakdown voltages for both RBDPO and MO under the presence of CuO. The lightning breakdown performances of RBDPO at different percentages volume concentrations of CuO are comparable with MO at positive polarity.

Keywords: Lightning breakdown voltage; nanofluids; non-uniform field; palm oil; transformers

INTRODUCTION

In recent years, there are number of studies that have been carried out on the application of nanoparticle in dielectric insulating fluids in order to improve its peformance. Various types of nanoparticles, such as conductive Magnetite (Fe_3O_4), semiconductive Titanium (IV) Dioxide (TiO_2), Copper (II) Oxide (CuO), and non-conductive

Aluminium Oxide (Al_2O_3) had been tested with different base fluids [1-3]. Properties such as AC, lightning breakdown performances, thermal properties, ageing and viscosity were normally monitored in order to find any improvement caused by the nanoparticles [1-7]. It is reported in [5] that, mineral oil experienced 24% increment of lightning breakdown voltage under the presence of semiconductive, TiO_2. Several studies also found that nanofluids such as silica, Zinc Oxide (ZnO) and TiO_2 could improve the AC breakdown voltage of MO [3, 6].

Due to strong interest in green technology and environmental safety purposes, vegetable oils are proposed as dielectric insulating fluid in transformers. The performance of vegetable oils are found to be satisfactory but there are several improvements especially on the dielectric properties that can be carried out through introduction of nanoparticles [8, 9]. In one of the study in [9], it was found that the introduction of Fe_3O_4 could cause 20% increment of AC and 37% of lightning breakdown voltages of natural ester and rape seed based oil. A number of works also have been carried out on Palm Oil (PO) for application in transformers [10-14]. The lightning aspects of PO were well examined in [12, 13]. Currently, there are less studies that have been carried out on the lightning breakdown voltage performance of PO under the presence of nanoparticles.This study aims to examine the lightning breakdown voltages characteristics of Refined, Bleached and Deodorized Palm Oil (RBDPO) Olein under the presence of CuO. All samples were tested at non-uniform field under positive and negative polarities.

MATERIALS

RBDPO Olein was used in this study. MO was used as benchmark in this study. Based on the manufacturer datasheet, the RBDPO contains 45.4 g of saturated fat, 11.6 g of polyunsaturated fat, 43 g of monounsaturated fat, 4.4 mg of vitamin E and 264 µg of vitamin A. The type of nanoparticle used in this study was CuO and the basic properties can be seen in Table 1.

Table 1: Basic properties of CuO nanoparticle

Properties	CuO
Size	< 50 nm particle size (TEM)
Color [15]	Monoclinic crystals or black powder
Density (g/cm^3) [16]	6.315
Molecular weight (g/mol)	79.55

EXPERIMENTAL

Preparation of CuO Nanofluids

The percentages volume concentrations of CuO used in this study were 0.001%, 0.025% and 0.05%. The oil volume used for the lightning breakdown test was 300 ml.

The mass of CuO used for synthesis of nanofluid were calculated and shown in Table 2. The CuO nanoparticle were dispersed into the RBDPO and MO by the magnetic stirrer for at least 30 minutes before tested.

Table 2: Mass of nanoparticles used at different percentages volume concentrations of CuO

Oil samples	Volume of concentrations (%)	Mass of nanparticles (g)
1	0	0
2	0.001	0.0189
3	0.025	0.4736
4	0.050	0.9473

Test Setups

The lightning breakdown voltage test configuration is shown Figure 1. The nanofluids samples were filled in a 300 ml cylindrical Perspex test cell according to IEC 60897 [15]. A needle-sphere electrodes configuration was used in this study where the copper needle has tip radius curvature of 50±5 µm and diameter of the grounded copper sphere was 12.7 mm. All tests were carried out at gap distance of 25 mm using the standard positive and negative lightning impulse of 1.2/50 µs that delivered by the TERCO impulse generator. Rising voltage method was used to determine all the breakdown voltage for all samples. The initial voltages were set at 50 kV and 100 kV for both positive and negative impulse respectively with the step increment voltage of 10 kV. The testing was repeated after standing time intervals of 3 to 5 minutes. A total of 10 breakdown voltages were recorded and mean breakdown voltages were calculated for each samples.

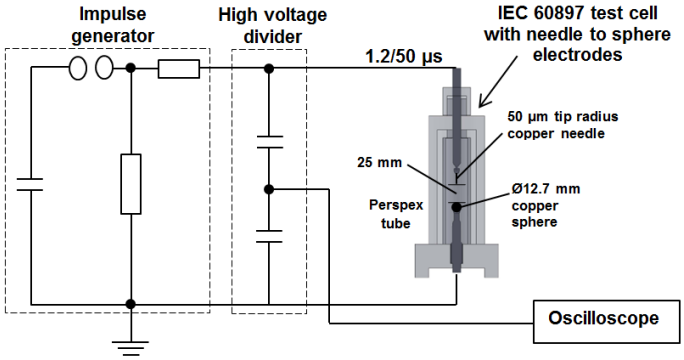

Figure 1: Test configuration for the lightning impulse

RESULTS AND DISCUSSION

Figure 2 shows the positive and negative lightning breakdown voltages for both samples RBDPO and MO at 0.001%, 0.025% and 0.050% of CuO. The lightning breakdown

voltages for all samples increase slightly with the addition of CuO under both positive and negative polarities where the percentages of increments ranging from 1.4% to 10%. Under positive polarity, the highest increments of breakdown voltages for RBDPO and MO are 5.9% and 7.7% as shown in Figure 2 (a). It is found that the breakdown voltages of RBDPO and MO are quite comparable with each increment of percentage volume concentration of CuO. The highest percentage of difference between MO and RBDPO occurs at 0.025% of CuO. The breakdown voltages of RBDPO and MO at 0.05% of CuO are 79.7 kV and 81.5 kV respectively.

The lightning breakdown voltages of RBDPO and MO under negative polarity are higher than positive polarity as shown in Figure 2 (b). In addition, the increment trends of breakdown voltage of RBDPO and MO under negative polarity are much apparent than under positive polarity. The highest increment rates for RBDPO and MO under negative polarity are 8.5% and 10% as compared to under positive polarity where the rates are 5.9% and 7.7% respectively. The highest difference between breakdown voltages of RBDPO and MO can as high as 14.4%.

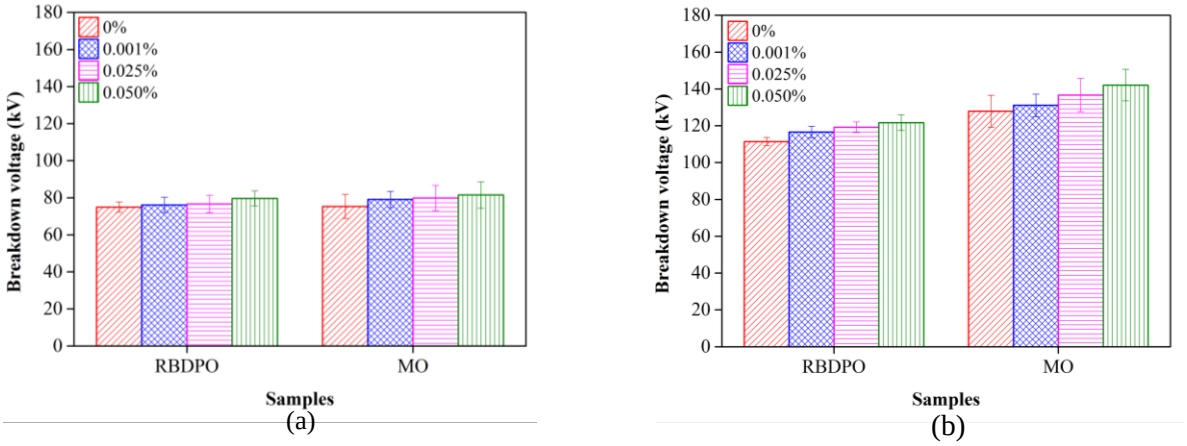

Figure 2: Lightning breakdown voltages of RBDPO and MO at different volume concentrations of CuO under (a) positive and (b) negative polarities

CONCLUSION

Based on the lightning impulse study under non-uniform field, it is found that there are slight improvements of the breakdown voltages for both RBDPO and MO under the presence of CuO. It is found that the increment trend of breakdown voltage for RBDPO is in-line with MO. This finding is promising as it shows that the withstand capability of RBDPO can be improved through addition of CuO.

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