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COMPARATIVE ANALYSIS OF STABILITY AND DIELECTRIC BREAK DOWN STRENGTH OF TRANSFORMER OIL BASED NANOFLUIDS

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ABSTRACT

Transformer oil is used as insulating as well as heat transfer liquid. If it is used for a long time it may loses its insulation and heat transfer characteristics. Nanofluids are the recent generation heat transfer fluids which are made by dispersing the nanoparticles in the required proportion to improve its properties. In the present study, breakdown strength and stability are measured for transformer oil based SiO_2, Al_2O_3, TiO_2 *nanofluids for various concentrations. It is observed that the breakdown strength increases with increase in the nanoparticle volume fixation up to a particular concentration and then it starts decreasing. Among the three types of nanofluids, transformer oil-*Al_2O_3 *nanofluid got the better performance in terms of breakdown strength and stability in terms of zeta potential value. Transformer oil-*Al_2O_3 *nanofluid showed the superior improvement in breakdown strength 32 % i.e., from 50 kV to 68 kV at 0.06 % volume fraction and zeta potential value is increased from 22 mV to 28 mV which is 27%.*

Key words: Breakdown strength, Nanofluids, Transformer oil, absorbance.

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1. INTRODUCTION

New generation colloid liquids are called nanofluids which are prepared by dispersing nanosized particles into the carrier fluid to improve the thermos-physical properties. In earlier literature, scientists have tried mixing micro sized particles into the base fluids to strengthen the properties. But due to the larger size of the particles, they tend to settle faster and becomes resistor rather than improving the performance of the base fluid. Generally mineral oil or synthetic mineral oil is used as a transformer oil. Transformer oil is utilized in transformers as an insulating liquid as well as heat transfer liquid. It should have good thermal conductivity, viscosity, chemical stability and breakdown strength. Nanofluids are prepared in a systematic manner using single point strategy and two stage strategy. Generally two stage strategy is the most commonly used method for preparing metallic oxide nanofluids. In this technique, first nanoparticles are manufactured by chemical methods like vapour deposition or mechanical methods like ball milling and then those nanosized particles are dispersed in base fluid in the required proportion. Sequence of operations involved in preparation of nanofluids using two stage method is shown in Fig.1.

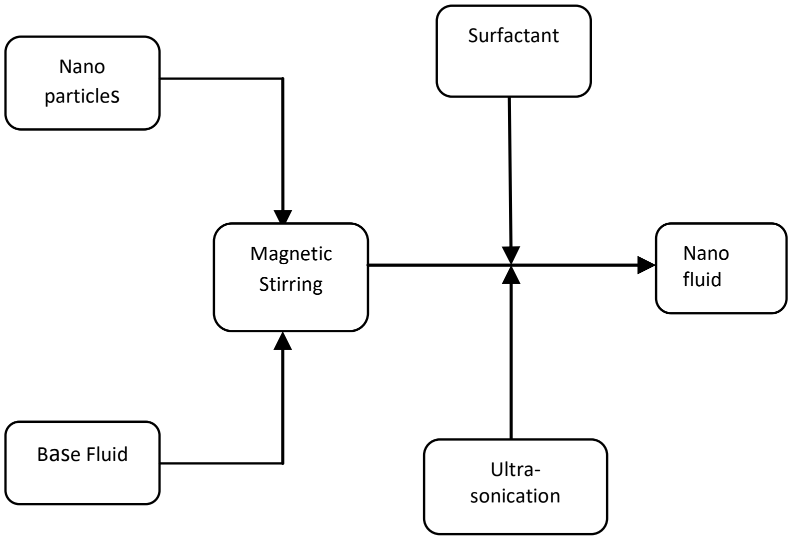

Figure 1 Sequence of operations in preparation of nanofluids.

2. LITERATURE REVIEW

Dong et.al [1] experimentally studied transformer oil based silica nanofluids and clarified the cause for the enhancement in breakdown insulation strength based on electrical double layer structure. Atia et.al [2] prepared transformer oil-titania nanofluids for demonstrating the dispersion behavior and breakdown strength for various particle fixations. With the help of Weibull distribution, probability of breakdown for all samples was found for all types of nanofluids and compared to the base fluid and observed 27% of improvement in dielectric strength. Wang et.al [3] synthesized three transformer oil based non-conductive, conductive and semi conductive nanofluids using Al_2O_3, Fe_2O_3, and TiO_2 nanoparticles with various volume fraction ranging from 5% to 40% W/V and measured dielectric strength and compared with base fluid. Rafiq et.al [4] reviewed the properties of nanofluids, opportunities, ecological circumstances, pros and cons, possibilities of potential application of transformer oil nanofluids. Asefi et.al [5] prepared transformer oil-diamond nanofluids for analyzing the stability, electrical and thermal properties and perceived the enhancement in dielectric breakdown strength of the prepared nanofluid. Lv et.al [6] prepared titania-transformer oil nanofluids and investigated the influence of scattering methods like magnetic stirring duration, duration of different ultrasonic methods on stability and dielectric strength and identified the clear cut dependency on the dispersion method. Ravi babu and Sambasivarao [7] prepared transformer oil based alumina nanofluids and measured breakdown voltage enhancement and absorbance using TAGUCHI design of experiments methods to eliminate the tedious repetitive experiments and experiments were carried out using L25 orthogonal matrix with process parameters like volume fraction (ϕ), span of sonication (hrs) and ratio of surfactant volume to nanoparticle volume fraction and proposed a correlation for breakdown voltage and absorbance. In the present work, breakdown strength and stability are measured for transformer oil based SiO_2, Al_2O_3, TiO_2 nanofluids for various concentrations.

3. PREPARATION OF NANOFLUID

Transformer oil based SiO_2, Al_2O_3, TiO_2 nanofluids are prepared using two stage preparation method. SiO_2, Al_2O_3, TiO_2 nanoparticles were bought from Nanolabs, India and those are at molecule size 30-50 nm, pureness 99.5%, explicit surface area 120-140 m^2/g were taken in appropriate amount (determined from eq. (1)) proportionate to the ideal nanoparticle volume division and scattered in transformer oil (Nexton Lubricants, India) to get ready alumina-TONF utilizing two stage technique. Nanopowder amount was estimated utilizing advanced digital balance (Make - SHIMAZDU). Oleic acid was utilized in required extent as surfactant so as to alter the outside of alumina particles. An magnetic stirrer (Make-REMI) with 1litre blending limit, 150 Watt warming limit and most extreme speed of 1800 Rpm was utilized to mix at first for 30 minutes and is appeared in Fig.2 then it was sonicated utilizing a ultrasonic sonicator horn (Make-Oscar Electronics) with 500 W power rating, 20 kHz recurrence and 110 V working voltage limit with regards to various sonication times. For at regular intervals of sonication time, a brief break time was given to abstain from overheating. Magnetic stirrer and Ultrasonic sonicator are appeared in Fig. 2(a) and 2(b) individually.

$$\text{Volume fraction} = \frac{v_{np}}{v_{np} + v_{bf}} = \frac{(m_{np} / \rho_{np})}{(m_{np} / \rho_{np}) + (m_{bf} / \rho_{bf})} \tag{1}$$

(a) (b)

Figure 2 Pictorial of (a) Magnetic stirrer (b) Ultrasonic Sonicator

4. MEASUREMENT OF BREAKDOWN STRENGTH, ZETA POTENTIAL

AC breakdown voltage has been estimated utilizing an oil analyzer (Make-High Voltage, India) appeared in Fig. 3(a). The test anodes were picked in agreement to Israel Electric Corporation (IEC 156) standard. As indicated by this norm, the gap separating was set to 2.5 mm and the voltage slope rate was 2 kV/s. All estimations were finished at room temperature. The oil analyzer utilized can gauge the breakdown voltage up to 80 kV. For each example, five estimations were taken with five minutes break between each test and the normal breakdown voltage is determined. Breakdown voltage of the nanofluid following one day was likewise estimated. Zeta potential is the expected distinction between the mass liquid which is far away from the nanoparticle and the fixed layer of liquid struck to nanoparticles. Zeta capability of the readied water-alumina nanofluid was estimated utilizing Zetasizer Nano arrangement (Make-Malvern Instruments, UK) which deals with Laser Doppler Electrophoresis rule. Diagram of zetasizer is shown in Fig. 3(b). For every estimation, another zeta cell is to be utilized and it must be cleaned completely utilizing de-ionized water and followed by ethanol. Prior to cleaning the zeta cell, water and ethanol should be sifted with smaller scale level pore estimated film channels. At that point the fluid example is filled in the phone with the assistance of a needle.


(a)

(b)

Figure 3 (a) Dielectric breakdown voltage measurement device (b) Zetasizer

5. RESULTS AND DISCUSSION

Breakdown strength is measured for the prepared transformer oil – SiO_2 nanofluid and compared with Dong et.al [1] for the validation of the result. Dielectric strength of the transformer oil - SiO_2 nanofluid for various volume fractions starting from 0 to 0.1 % and observed the percentage of error as 2.5 % at 0.1 volume fraction. Validation of breakdown strength measured oil tester is shown in Fig. 4.

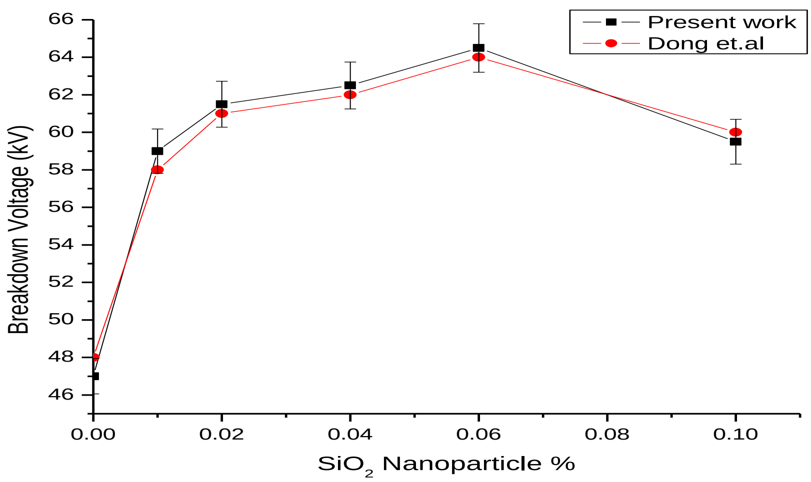

Figure 4 Validation of breakdown strength instrument [1]

After validating the instrument, breakdown strength is measured for other prepared transformer oil based Al_2O_3, TiO_2 nanofluids. It is observed that breakdown voltage is improved with increase in volume fixation of nanoparticle from 0.01 % to 0.1 %. Fig.5 shows the variation of dielectric breakdown strength for transformer oil - SiO_2, Al_2O_3 and TiO_2 nanofluids. It is observed that nanofluid prepared using transformer oil - Al_2O_3 shown better performance in terms of break down voltage. Maximum percentage of improvement in the dielectric strength is observed for transformer oil - Al_2O_3 nanofluid at 0.06 % of volume fraction.

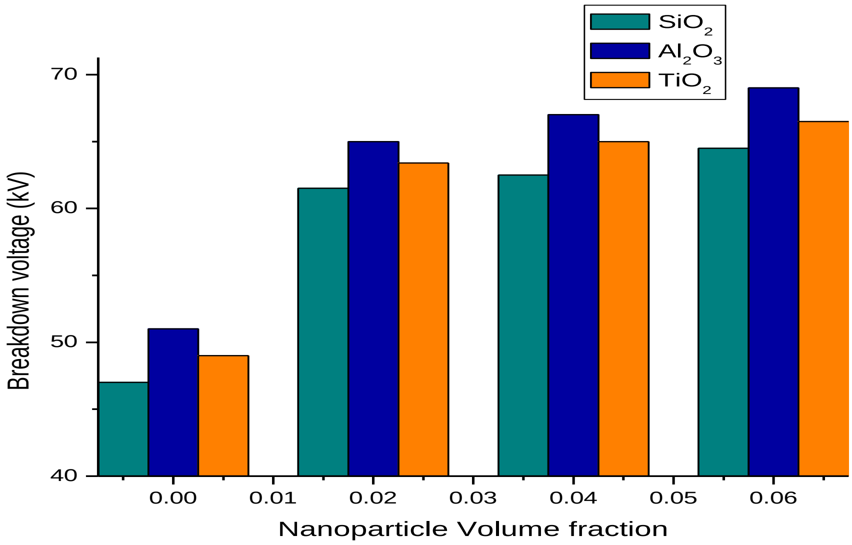

Figure 5 breakdown strength of various nanofluids at different volume fractions

Stability is measured in terms of zeta potential value of the prepared nanofluid. Zeta potential is measured for the TiO_2 nanofluid and compared with Atia et.al [2] and observed the maximum percentage of deviation is with in ± 5%.

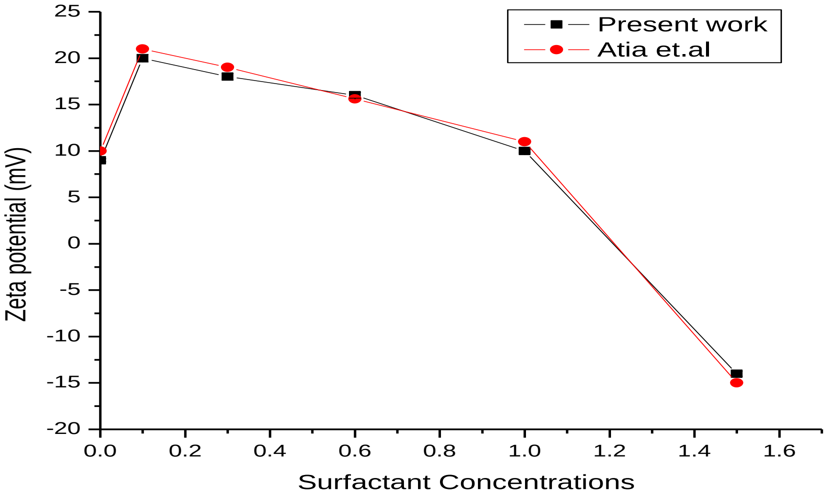

Figure 6 Validation of zeta potential for TiO_2 nanofluids [2].

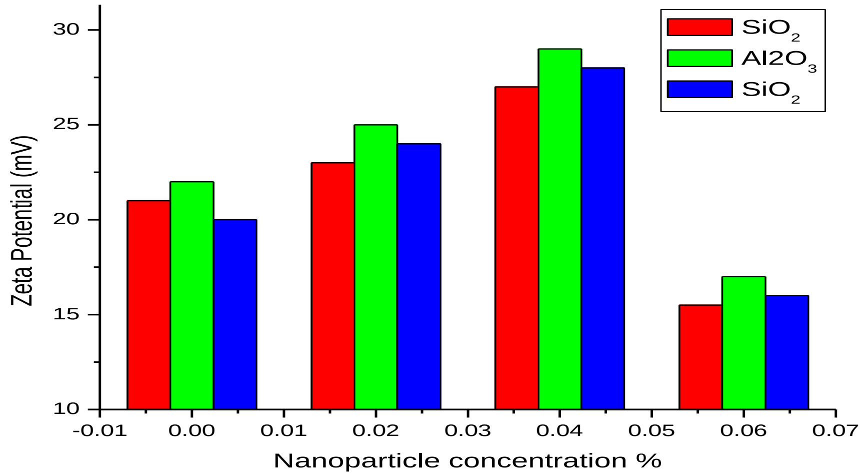

Figure 7 Comparision of zeta potential values for various nanoparticle concentration.

Validation of zeta potential values by comparing with literature is shown in Fig. 6. After validation of the instrument, zeta potential values are measured for estimating the stability of the prepared nanofluids and shown in Fig.7. It is observed that transformer oil – Al_2O_3 nanofluid shows good stability compared to other prepared nanofluids. It is also observed that good stability also leads to good breakdown strength for the test fluid.

6. CONCLUSION

Present study is devoted to measure breakdown strength of various transformer oil based nanofluids which are prepared by dispersing SiO_2, Al_2O_3, TiO_2 nanoparticles in carrier fluid. It is observed that the breakdown strength increases with increase in the nanoparticle volume fixation up to a particular concentration and then it starts decreasing. Among the three types of nanofluids, transformer oil-Al_2O_3 nanofluid got the better performance in terms of breakdown strength and stability in terms of zeta potential value. Transformer oil - Al_2O_3 nanofluid showed the superior improvement in breakdown strength 32 % i.e., from 50 kV to 68 kV at 0.06 % volume fraction and zeta potential value is increased from 22 mV to 28 mV which is 27%.

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