Develop the thermal and electrical transformer oil by Barium Titanate nanopowder Ba/TiO_3 addition

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Abstract

In this paper, Barium Titanate cubic nano powder Ba/TiO_3 is added to transformer oil in order to enhance the electrical insulation and thermal conductivity of Barium Titanate nano oil (BTNO). Thermal conductivity, breakdown voltage, and AC resistivity of samples for pure oil and five percentages (0.01, 0.02, 0.03, 0.04, and 0.05%) w/w were measured. However, Oleic acid as a dispersing agent was added in a ratio of 0.02 w/w to 100 ml. of oil. It was discovered that BTNO had up to 1.5 times pure oil's thermal conductivity, breakdown voltage, and AC resistivity. The addition increased the oil's electrical resistance and internal cooling capacity. Including nano powder increased the useful life of the used oil and decreased the requirement for routine maintenance. Furthermore, it is strongly suggested—but with caution—to add oleic acid to manage the dispersing agent. Therefore, carefully monitoring the dispersion agent's addition is highly advised.

Keywords: cooling oil, dispersion agent, thermal conductivity, and nanofluid.
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1. introduction

Electric transformers are often used in transmission and distribution systems for electric electricity.[1]A hypothetical transformer failure would be destructive since the transformer utilized in the electrical system transforms voltage and current and transfers energy. Most power transformers are either closer to or extend beyond the traditional configuration. According to the data on transformer failure, insulation breakdown caused the average transformer to stop working after 17.8 years.[2]Therefore, it is crucial to pay more attention to research projects that enhance transformer cooling performance. When a transformer malfunctions, issues with the distribution network's operation increase the cost of running the power system and decrease the reliability of electricity delivery. The popularity of oil-cooled transformers is a result of the fantastic cooling method. It has dielectric oil in it for cooling and insulation purposes.[1]Transformers use cellulose, insulation material, and transformer oil as a cooling medium. One of the essential characteristics of transformer oil is breakdown voltage (also known as dielectric strength). [3]Using nanoparticles is a quick fix and a growing area of study for improving insulating materials' dielectric and thermal properties.[4]Therefore, there is growing interest in improving transformer oil's dielectric and thermal properties using cutting-edge technologies like nanotechnology.[1]When they create a nanocomposite, the oxide nanoparticles, in particular, significantly impact physical properties. [5]The dielectric and thermal characteristics of transformer oil have occasionally been the subject of numerous studies. Most of these studies primarily aim to use nanofluid techniques to enhance the electrical and thermal properties of the oil. This oil can be combined with nanoparticles like Al, AL_2O_3, Cu, and others in various ways. According to [6-12], several researchers looked at the electrical characteristics of transformer oil combined with nanoparticles. They discovered that the breakdown voltages of the nanofluids were substantially higher than those of pure transformer oil. The thermal qualities of introducing Nano molecules to transformer oil were investigated by some researchers, who found an improvement above virgin transformer oil.[13, 14]

Discuss the employment of semiconductive nanoparticle in this study as it controls charges inside the oil, works on material internal control, and understands the full degree of their electrical and thermal influence. In the current study, transformer oil-based nanofluids are prepared using high thermal conductivity barium titanate nanoparticles, and their thermal and electrical properties are examined. Ba/TiO_3 nanoparticle oil suspensions are anticipated to offer higher thermal conductivity than pure transformer oil while maintaining dielectric properties because their thermal conductivity (roughly 1,3 to 6 W/m.K.) is significantly higher than that of pure transformer oil (about 0.115 W/m.K. at room temperature).

2. Experimental work

The experimental methods for making transformer oil that is nanofluid are described. Additionally, three tests using six different weight ratios were conducted. In the first experiment, semiconductor nanostructures (Ba/TiO_3) were used to assess the breakdown strength of nano-filled transformer oil. The material's Ac Resistivity or dielectric was measured in the second experiment after the nanoparticles were added. Finally, the third experiment measures mineral oil's thermal conductivity increases or decreases when nanomaterials (Ba/TiO_3) are added.

2.1 Materials and Methods

Transformer oil was altered by introducing Ba/TiO_3nanoparticles (NBT). This method used cubic Ba/TiO_3nanoparticles made by a US business as the NBT in this study (sky spring). Ti, O_3, and Ba are the three components of the product, which are nonlinear, ferroelectric, and high density. The mineral oils dispersed in the oil utilized in this investigation were made in Sweden (nynas). The medication is supplied as a liquid by Central Drug House (P) LTD. at 7/28 Vardaan House, Daryaganj, New Delhi-110002 and exhibits high oxidation stability and strong resistance to oil degradation (INDIA). Table 1 contains the material specs that were employed. [2]

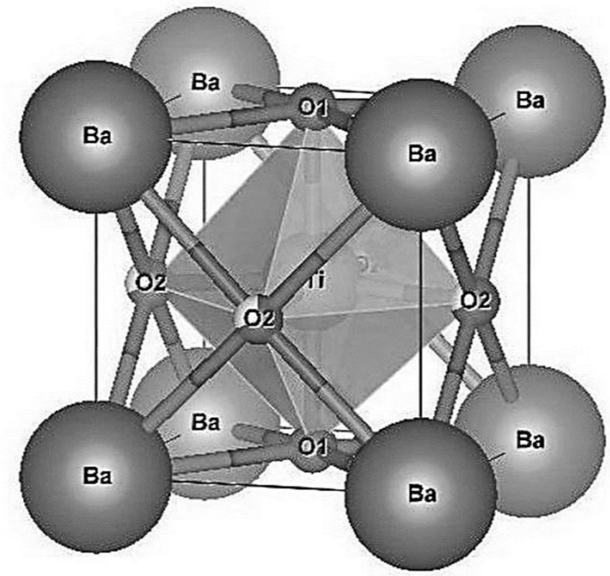

Fig. (1) Structure of Ba/TiO_2

Table 1. Specification of the materials used in this study

Materials	Properties
Transformer oil	Mineral oil liquid , flash point=>140˚C ,Density=0.085g/cm^3white nano
Nano Ba/TiO_3	powder (purity 99.9%,50-70nm,cubic) ,density=5.85g/cm^3 liquid
Oleic acid	,color=pale yellow, density =0.89g/cm^3

* Supplied by the product data sheets.

The Department of Materials Sciences at Technology University is where the experimental study was completed. In a typical laboratory setting, a scale and vacuum are used in conjunction with lubricating oil and nanomaterials that are weighed at 0, 1, 2, 3, 4 and 5 per cent of NBT (nanoparticles Ba/Ti O_3), respectively. Additionally, they were combined with 100 ml to create the nano oil. The nano oil was then combined with 0.2 weight per cent of oleic acid (the dispersing agent), a surfactant. To create the NBTNO (nanoparticle Ba/Ti O_3 nano oil), they combine the produced oil using two different techniques. The two-step procedure is the most effective and popular way to prepare samples of various NBT. The NBTNO is prepared using magnetic stirring mixing techniques and ultrasonic ways. For 20 minutes, a magnetic stirrer employs a rotating magnetic field to homogenize the mixture. In order to stir the solution and enable the rotation of small magnetic bars in an exciting mixture, they apply an external magnetic field to magnetic stirrers. As a result, the magnetic field's rapid rotation causes the bar magnet to rotate, swirling the liquid. In this process, the NBT is prepared by ultrasonication, and the NBT is combined directly with the carrier fluid. Sludge disintegration is accomplished mechanically via ultrasonication. Sound waves stir particles in a solution up for 30 minutes at 50 ^{0}C and 480 watts. The medium's transmission of ultrasonic waves causes periodic compression and rarefaction. Ultrasound wave propagation causes microbubble formation in the medium. Tiny bubbles, when they reach a crucial size, they suddenly collapse within a few microseconds and trigger cavitation. Extreme circumstances result from microbubbles violently collapsing. Because fundamental characteristics like electrical permittivity and conductivity substantially impact the dielectric performance of oil, choosing the right NBT to improve dielectric and thermal properties is a complicated procedure.[2]

2.2 TEST CASES It was done to ensure that the sample NCBTF could potentially replace mineral oil. If a sample passes all necessary tests and the values of the results are within the bounds given forth by the standard, it is appropriate for consideration. Improved outcomes demonstrate that the sample NBTF is suitable for usage as transformer oil.

2.2.1 Breakdown test The device depicted in Fig. (3), where the oil is inserted between the spherical brass electrodes (the brass electrodes are immersed in oil), was used to assess the strength of the electrical breakdown. The oil's surface had to contact the brass electrodes during the test directly. After the gadget is turned on, the voltage increase time is calculated. The electrical breakdown happened at a specified voltage value presented on a digital screen on the lower left side of the device when the test started, and the electrical breakdown was computed using the relation (1). The electrical breakdown strength's voltage rise rate time at room temperature is 0.5 kV/s. [15]

$$Ebr = \frac{Vbr}{d} \quad (1)$$

E_{br}	(kV/mm) Electricity breakdown strength
D	between-electrode distance (2.5 mm).
V_{br}	breakdown voltages (kV).

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$$I_{cr} = \omega \varepsilon_{\circ} \varepsilon r \tan\& \quad (2)$$

ω	2πf (f: frequency =50Hz).
$\varepsilon_{\circ}$	vacuum permittivity (8.85×10-12 F/m).
ε_r	dielectric constant. $\varepsilon r = [(\frac{C_p}{\varepsilon_{\circ}} . \frac{d}{A})]$ Cp: capacitance when RLC parallel circuit, d: Thickness A: Area
tanδ	loss tangent.

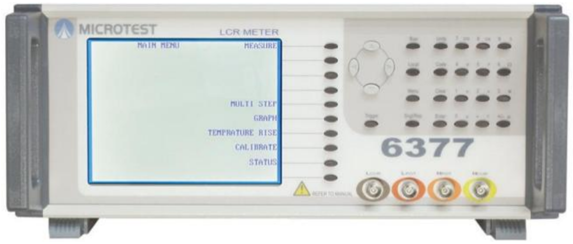


Fig (4) the device (Microtest/LCR Meter/ Type 6377 (0-1MHz) Taiwan)[14]

2.2.3 Thermal Conductivity Test Using the instrument Lee's disk model made in England, this test is carried out by the requirements of IEEE standard NO 442-2017. the measurements of thermal conductivity (K in W/m.k units). The specimen's thermal conductivity is measured using Lee's disk method when its thickness (ds) is tiny compared to its diameter (D). Since the disk's cross-sectional area, ($A = \frac{\pi D^2}{4}$) Suppose high compared to the edge's exposed area , the aspect ratio eliminates the need to take heat loss from the die's edge into account. The system will approach thermal equilibrium more quickly if a thin specimen is used. Without accounting for heat losses from the disk's edge, the heat transfer (Q) over the specimen's thickness is given by (3): [17]

$$Q = \frac{KA(T_U - T_M)}{d_s} \quad (3)$$

Where the temperature differential across the specimen is (T_U - T_M) (Fig.5a). In conjunction with a heat source, the thin specimen is positioned between two brass disks in (Fig.5b). Brass disk (1) temperature can be expected to be extremely close to that of CBTF surface due to CBTFlower heat conductivity when compared to brass. The temperature of the brass disk (2) can be considered similar to that of the other oil surface. Allows for measuring the (T_U-T_M) temperature difference across the specimen. At equilibrium, the rate of heat loss via cooling equals the rate of heat entering the brass disk (2). The heat loss may be calculated by measuring the cooling rate at the equilibrium temperature.T_M (with the insulation pad shown in Fig. 5C covering the brass disk (2)). The rate of heat loss is given the disk cools at dT/dt.[17, 18]

$$\frac{dQ}{dt} = m\, c_p \frac{dT}{dt} \quad (4)$$

m	the brass disk's mass
cp	Brass's particular thermal capacity

Considering that the specimen's heat flow is the average of the amounts of heat that flow into and out of it, the following follows:

$$K\frac{T_U - T_M}{d_s} = h[T_M + \frac{2}{r}\left(d_M + \frac{1}{4}d_s\right)T_M + \frac{1}{2r}d_s T_U] \quad (5)$$

T_U	Disk temperature (U)
T_M	Disk temperature (M)
r	a disk's radius
d_M	the disk's thickness M
d_s	When the temperature of the disk is one degree higher than the enclosure, the thickness of the disk (S) (specimen) heat loss per second/cm2
h	Disk temperature (U)

The h or heat loss determined from following equation:(6)

$$h = \frac{H_t}{\pi r\,(T_C - T_M)r + 2\left[d_M T_M + \frac{1}{2} d_s (T_M + T_U) + d_U T_U + d_c T_c\right]} \quad (6)$$

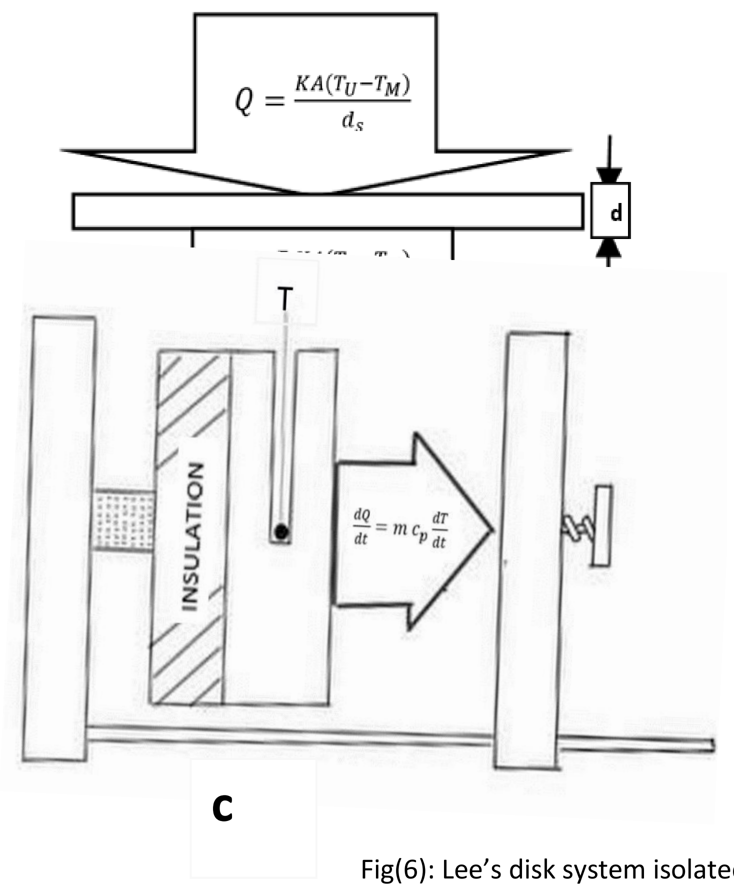
where dc and Tc : thickness and temperature of disk(c) respectively. Lee's disk system Fig(6) is isolated from external effects by using glass desiccator's Fig(7).

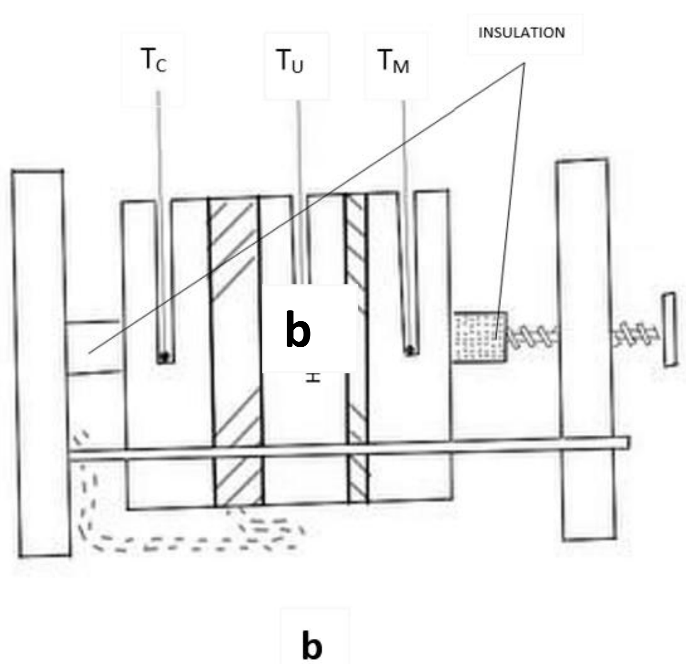
When the system is linked to an electric power supply; then the power in watt is:

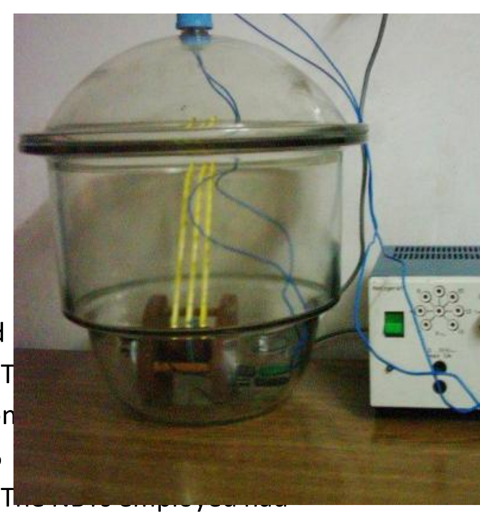
$$H_t = IV (7)$$

V	The Voltage (6 V).
I	the current equal to 0.25 A.

The dimensions of device is r =20.7 mm and d_M= d_U= d_C= 13 mm.[17]







Fig(6): Lee's disk system isolated by glass desiccator's

3. Experimental Results

The NBT demonstrates an electron scavenging mechanism that transforms rapid negatively charged particles in the insulating fluid under electrical stress. The NBT a ferroelectric type based on conductivity, relaxation time constant, and electron (0- 0.01- 0.02- 0.03- 0.04- 0.05) g/L in mineral transformer oil with 0.2% sedimentation, si ples each of barium titanate Nanoparticles were created. T

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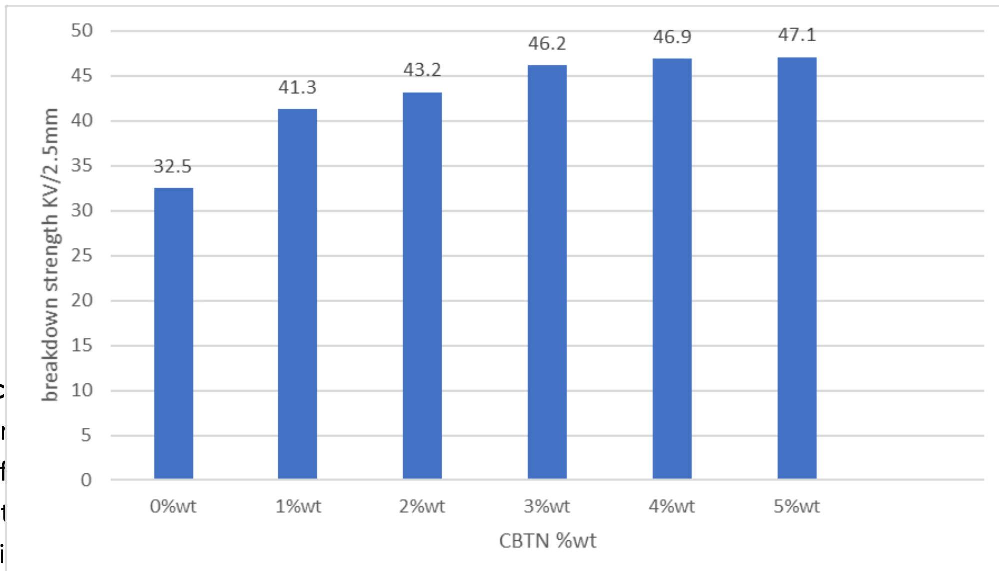
an average size of roughly 50 nm. These NBTNO were thermally and electrically coupled with mineral oil. The setting was 25 ºC, or room temperature..[2]

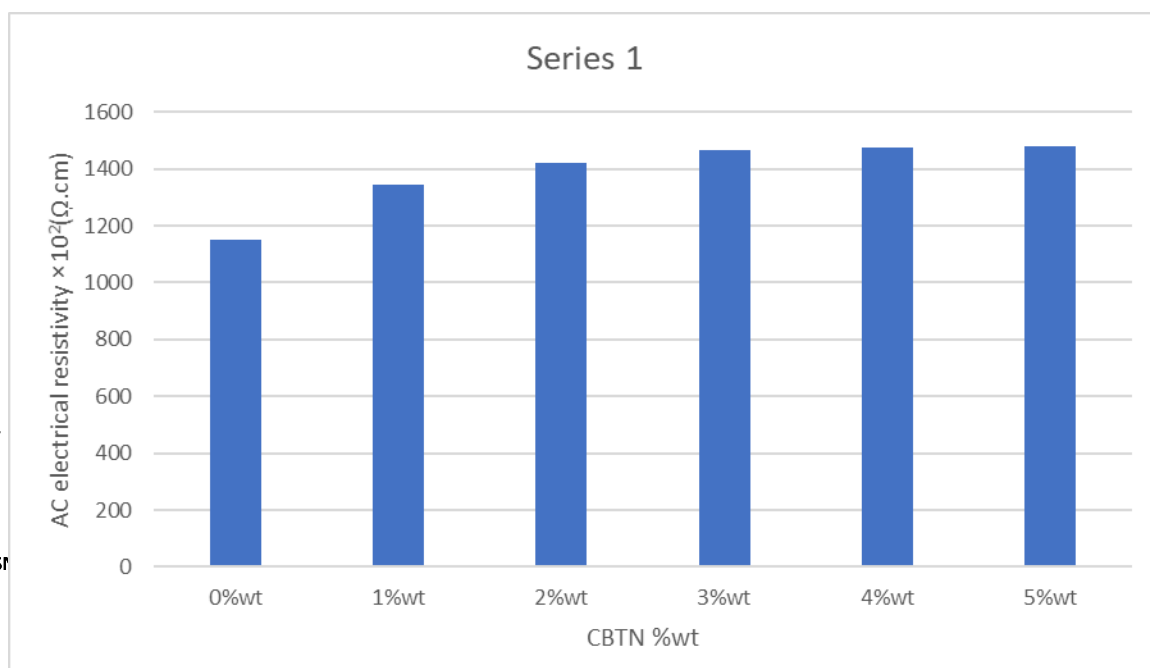
3.1 Breakdown test rustle

This test aids in assessing insulating qualities. The breakdown voltage for Ba/TiO_3 has the lowest standard deviation of any NBT and is also the highest. It is because ba/TiO_3 distributes the produced electric field and prevents the streamer from accumulating. Compared to virgin transformer oil, there is a considerable (27-32.9-42-44.3-44.9)% increase in the breakdown. Figure 7 shows how significantly the breakdown strength is improved by NBT when added to the oil. It is explained by the fact that Ba/TiO3 prevents the electric field from building up. Because the NBT disperses the produced electric field, the breakdown voltage is more significant.[2]



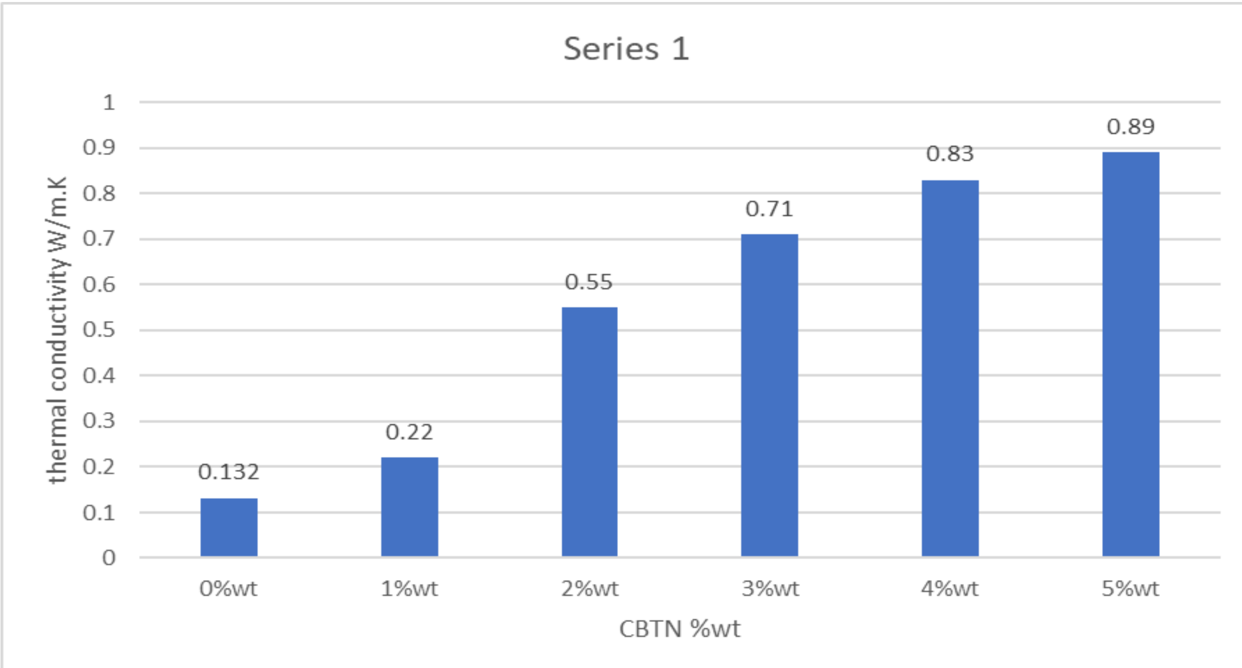
3.2 Ac

The pr ... cal resistivity. Theref ... esistivity value indicat ... 8 displays the electri ... ncrease in the typical values of transformer oil that demonstrates the noticeable improvement brought on by the addition of nanomolecular, which raises the oil's quality by (16-23-27-28-28.5)%.in comparison to virgin transformer oil.[19]



3.3

At 1% wt of nanoparticles, the thermal conductivity of suspended spherical Ba/TiO_3 in transformer oil increased by more than 66%. However, as the concentration of the suspended particles rises, so does the viscosity of nanoparticle-oil suspensions. As a result, the particle concentration cannot continually grow. In addition, it is noteworthy that the rod-shaped particle is more conducive to heat transfer than the spherical particle but experiences dispersion instability when the aspect ratio of the particle increases. [20]



Fig(9) thermal conductivity for all samples.

4. Conclusion

Compared to pure oil, barium titanate nano oil mixes exhibit increased thermal conductivity, breakdown voltage, and AC resistivity. They are therefore excellent candidates for the next wave of heat transfer fluids. However, the heat transmission, viscosity, and chemical stability are adversely affected by the considerable rise in the weight ratios of nanoparticles. Oleic acid, when added to a combination in low weight proportions, serves as a dispersing agent and lowers the surface tension of Ba/TiO_3, improving the mixture's homogeneity and preventing nano molecules from bumping into one another. As a result, they provide a discernible improvement in terms of the thermal and electrical oil parameters.

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