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Corn Oil Performance's A Bio Cooling Fluid in Electric Distribution Transformer

Ahmed A. Khudhair [a]*, Mohammed H. Jabal [b], Samar J. Ismail [c]

[a,c] Electromechanical Engineering Dept., University of Technology-Iraq, Alsina'a Street, P.O. Box 10066, Baghdad, Iraq.
[b] Mechanical Engineering, University of Technology, Johor, Malaysia.
*corresponding author's E-mail : 19.33@grad.uotechnology.edu.iq

HIGHLIGHTS

- Study the thermal and tribological behaviour of the corn oil.
- The bio-lubrication obtained gives a decrease in the value of the Wear diameter.
- Laboratory prototype of electric transformer used for verifying the performance.

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ABSTRACT

Biodegradable (Vegetable) fluids are considered as environmentally friendly fluids and possess an abundant benefit, they are wildly available by means of renewable sources compared to different kinds of mineral-oil. Given the occurrence of environmental pollution and health problems from mineral oils. This paper investigates the effect of utilizing the corn oil for the cooling performing features of distribution electric transformer, and making a comparison with the cooling performance of the electric transformer whith cooling by the commercial mineral fluid. This investigation is done by using the four- ball machine and electric transformers. Each experiment that was executed complies with ASTM D4172-B under different electrical loads (200-1600W). Depending on the outcomes of the four-ball machine and electric transformer, it has been noticed that the corn oil has the adequate cooling behavior compared to the commercial cooling fluid. It maintains the insulation housing between the coils, and maintains the coils when overloaded at peak time.

1. Introduction

The electrical transformer is one of the most important elements of the electrical network for the transmission and distribution of electrical energy, as through it the electric voltage is raised or decreased, without changing the frequency. The single-phase transformer consists of two windings located above a steel core made of sheets made of silicone. A coil with fewer turns is called a low voltage coil, and a coil that has a greater number of turns of a high voltage coil [32] . Also, the coil to which the supply (AC) is connected is called the primary coil and the other is called the secondary coil to which the load is connected (Figure 1). Once the alternating current source of voltage V1 is given to the primary winding, an alternating flux is created in the magnetic core which is connected to the primary and secondary winding and thus, self-induced (EMF) E1 and mutual stimulator (EMF) E2 is induced in the primary coil respectively [31]. These emf induced in phase opposition to V1 were developed according to Lenz's law. The self-induced emf in the primary is also called back (E MF) since it operates in the opposite direction to the applied voltage [1]. Through the process of converting electrical energy in transformers, many types of losses arise. These losses usually occur in the active parts (windings and core) of the transformer and these losses will then be converted to heat [30]. This heat is spread throughout the transformer and then transmitted to the transformer body tank, through the insulation material (mineral oil) and then transmitted to the air. The accumulation of this heat, however, is without effective dissipation will damage the insulation paper and damage the transformer's windings [2]. An effective technology to support oil production has been found by professionals and researchers since the beginning of the nineteenth century, prompting the production of modest oily liquids. Such modest oils had an effect on greenhouses as well as serious heat problems in the atmosphere. Demand for biodegradable items expanded due to increased awareness of luxury and limited oil assets. Many efforts have been made to combat pollution, especially from oil-based oil. It was discovered that the climate was constantly polluted by discharging around 12 million tons of petroleum waste [3]. The biodegradable petroleum results obtained a viable alternative to regular petroleum due to contamination of natural materials. Besides, other types of bio-oils, for example, creature fats and vegetable oils, are used as options unlike mineral-based oils. It has been found that people in Egypt

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used in ancient times types of vegetable oils to create their landmarks [4]. This makes it safe to say that using vegetable oils at work can be appropriate. Advanced vegetable oils as a lubricant are based primarily on their degradable properties and secondly, they are less toxic than other oil-based oils. Moreover, vegetable oil is a sustainable source of creativity and labor. In addition, through examination, it was found that vegetable oils have better lubricating capacity compared to engineered oils and mineral oils when used between two moving metals.

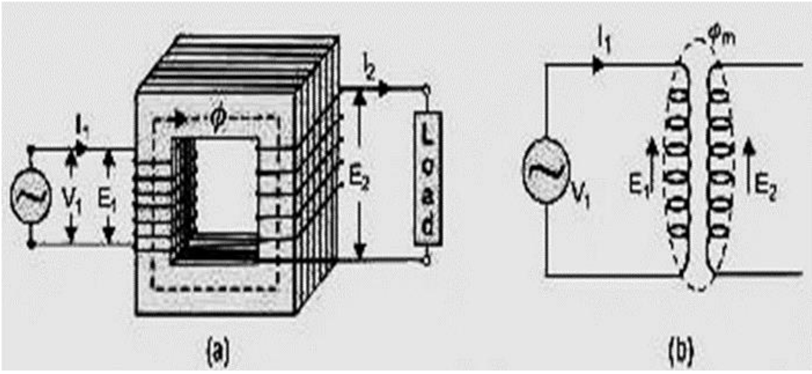

Figure 1: (a) Single – phase transformer (core and winding) (b) flux linking with primary and secondary[1]

This lubricating ability is due to the way in which vegetable oil contains an enormous amount of components saturated with ester and polarity that affect the sliding development of the two minerals. The oil also uses a natural isolation of esters (vegetable oils) extracted from natural plant seeds such as soybeans and rapeseed as an isolation and cooling method. It has many advantages over traditional mineral oil transformer. [5]. Moreover, vegetable oil contains a long percentage of unsaturated fats that have lipid properties prevalent at central fracture points. A compound attack test was performed to check vegetable oil and unsaturated fats at surface level [6] . It was discovered that during sliding developments, the mineral cleansing film is cleaned. Palm oil has been tried by many scientists for related applications, for example, as a fuel for diesel engines [7, 8]. Palm oil is a concentrated hydraulic fluid [10] . In addition, palm oil's qualities as a lubricant for tires were investigated by Syahrullail and colleagues [9, 10]. Crude palm oil can be isolated as a bio-liquid into several classes. The primary classification involves the use of 100% palm oil as a test ointment [11, 12]. Subsequent classification includes litigation over palm oil emulsion [13, 14]. The third classification includes the use of an additive mixed with palm oil [15, 22]. The fourth classification includes the use of palm oil as an additive [23]. The results obtained were promising and showed extraordinary potential that could be used in designing applications. However, the oxidation of vegetable oil must be considered among the various variables. The current work aims to explore corn oils to form a coolant using a four-ball machine and a prototype of a distribution transformer.

2. Experimental Method

2.1 Equipment

The Four-Ball Machine provides an assessment of the wear resistance and robust compressive properties of lubricants and greases at sliding contacts. This machine is widely used in tests, mainly to demonstrate performance in industrial applications such as greases. ASTM standard tests are well known in the industry and are used as a reference in many of the lubricant industry. A four-ball machine was used in the current study. Such a test was initially identified by [24]. It was previously obtained at a long-term site in the basic investigation of fluid properties. Figure 2 shows this device.

This tool uses four balls (made of AISI E-52100 chrome alloy. Ball details can be presented as follows: Width 12.7mm; Very clean rating 25; Hardness 64-66 Rockwell hardness C), and one steel ball is placed on the top while 3 steel balls are placed at the bottom. The three balls are placed securely in a round bowl, exposing the liquid and pushing the ball up. The most visible ball is the ball that is spinning at the required speed, while the lower shot balls make the ball more visible to hold in standby. Rotating the upper steel ball under load on three fixed steel balls coated with lubricant. Measurements are taken at rotating speeds, temperatures, and duration specified by published standards. The load and wear index can be calculated from the weld point in the EP tests, and the lubricant comparisons can be made based on the scar diameters incurred from the wear tests. A load of 392.4 N typical loads under (1,200 rpm) was applied as rotation speed for 1 hour time and 75 °C for liquid temperature in the present test, as shown in Figure 3.

The laboratory test device (electrical transformer) consists of the main components shown in Figures (4-5), and it is a scale model of an electrical transformer made of galvanized sheet (2.5 mm). An insulated coil is placed inside the laboratory model to generate a specified heat load , The core of the transformer is filled with approximately (1,750 ml) of cooling oil (mineral oil) and (corn oil). Six thermocouples installed in different regions are placed to read the temperature of the oil, of which (four thermocouples) are installed on the chassis of the model. (Two thermocouples) are placed inside the model, one in the upper part and the lower part of the oil inside the model. The thermocouples are connected by the data logger for the purpose of reading the temperatures when applying different loads to the model, as shown in Figures 4.

2.2 mineral oil

Transformer oil is a refined oil, at very high temperatures it is stable, it has the properties that it should be transparent, clear and clean under the light. The oil is light yellow in color, and at very low temperatures it does not solidify. Also, this oil must have the advantage of being able to cool down easily, the combustion point is very high, the breakdown voltage is high during the overload period, and it has resistance to oxidative decomposition, and the viscosity be low for the purpose of fast movement within the transformer. It should have the ability to cool easily and possess a high heat conduction property. In order to obtain the expected efficiency during work. All these properties of transformer oil are tested in certified laboratories. These tests are based on standards published by the American Society for Testing and Materials (ASTM), the International Electro Technical Commission (IEC), and the International Standards Organization (ISO).

2.3 The physical tests

That are examined for this oil are: Color check, The amount and size of pollutants, Traffic viscosity test , and Flicker test [29 - 33] . The device is shown in Figure 5.

2.4 The chemical tests

An oil includes a moisture test, a pH test, and a surface tension test [29- 33] . Figure 6 shows the device checking properties.

2.5 Electrical checks

Includes first , (Electrical insulation). This is the main examination in electrical transformers, through which the ablity of the oil to withstand the electrical load is known before the breakdown. Second, (Measurement of the tangent factor of the angle of separation). This test is performed to find out the amount of electric current flowing through the oil [29 - 33]. The examination device is shown in Figure 7.

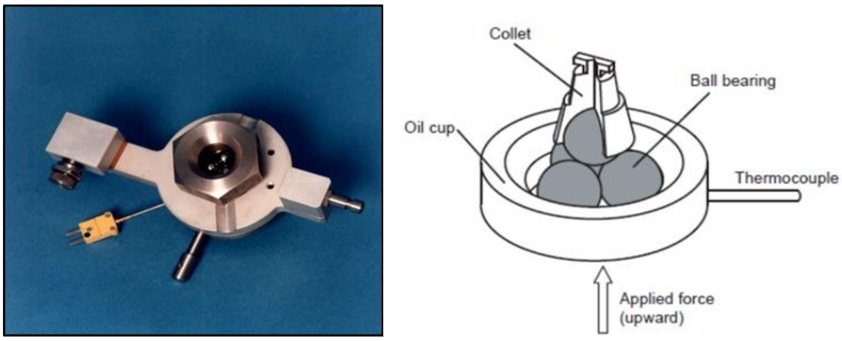

Figure 2: Four ball in device and ball in pot

Figure 3: Four ball machine

Figure 4: Electric transformer [33]

2.6 Examine the percentages of dissolved gases in insulation oils

This examination is considered one of the most important tests carried out on electrical insulating oils to measure the percentages of dissolved gases in the oil, such as hydrogen and acetylene [29-33]. The examination device is shown in Figure 8.

Mineral oils have been classified according to their use as a cooling and insulating agent over the years into the following: Polychlorinated biphenyl (PCB) Liquids, Modern transformer oils. The second type is mineral oil standards, and first type standards for mineral oils. List of tests for electrical insulating oils in the laboratory are shown in Table 1 [29- 33].

Corn oil and mineral oils were used in this study as cooling and insulation oil samples in electrical transformers. A comparison of the results obtained from any experiment was made with the results obtained by performing similar experiments using the American Society of Engineers' Mineral Fluid Trade (SAE 250). The experiment was designed to test 10 ml of fluid at a time. Now a comparison will be made between mineral and vegetable oils, as shown in Table 2.

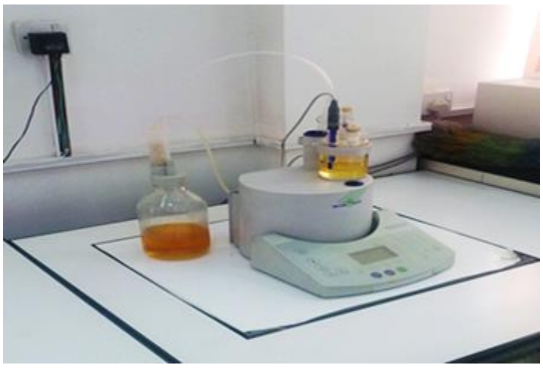

Figure 5: Oil physical properties tester

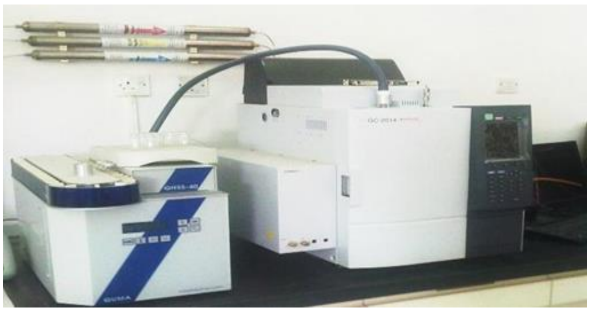

Figure 6: Oil chemical tests [29-33]

Figure 7: Electrical checks tests

Figure 8: Examination of the percentages of dissolved gases in insulation tests

Table 1: List of tests for electrical insulating oils

n	Type of examination	Method
1	Dissolved Gases	ASTM D 3612
2	Electrical insulation	ASTM D877, IEC 165,VDE 370
3	The tangential coefficient of the angle of separation	ASTM D 429
4	Water content (moisture)	ASTM D 1533 , PH ASTM D 974
5	Surface tension	ASTM D 971
6	Density Class	ASTM D 49
7	Viscosity	ASTM D455
8	Shape and color	ASTM D 1500
9	Quantity and size of pollutants	ISO 11171
10	Flash degree	ASTM D 92

Table 2: properties of mineral oil and vegetable oil

N	Properties	Mineral oil	Vegetable oil
1	Environmental performance	- Contains harmful, toxic and dangerous components in water and soil	-It contains no harmful ingredients, no toxicity and dangers to water and soil
	Biodegradation	Not biodegradable	Biodegradable.
2	good security	- The ignition point of oil is 160 ° C	-The ignition point of oil is generally above 350 ° C
	transformer fire explosion	more	less
	Ignition time	less	More
	Extinguishing time	longer	short
	smoke generation	huge	Lower

	Gas produce	Huge	Lower
	high-energy arc faults	huge	lower
3	electrical performance	- good	excellent
	- overload	-good	Good
4	properties	non-renewable	Renewable
5	aging of insulation paper	Reduces insulation strength	increases
	molecular polarity	lower	Greater
	water resistance	greater	Lower
	absorb moisture	Very low	Very high
6	cost	expensive	Cheap
7	Availability	Depending on the availability of crude oil	Abundantly in nature

3. Test procedures

In order to maintain the support of the steel balls, the entire parts comprising the four balls plus the round bowl were thoroughly cleaned with liquid acetone and then the parts were dried using a new mechanical wipe free of construction to ensure that there were no residues of any soluble materials. Then it is kept before assembling the parts and emptying the oil into the saucepan. To fix the core ball and put the three balls in position, a wrench was used for the purpose of connecting and fixing the metal pulleys. From that point onwards, the most noteworthy ball would be positioned and held in the collector and bound to the shaft. Finally, the stacked saucepan (bow) was filled with the liquid being tested. The oil level is shown to fill all the holes inside the mug (bow) together. For the purpose of fixing the vessel with the balls and the sample, a non-grating disc was used in the four ball apparatus as a stage to fix the bow portion on it. After that, the load (392.4N) was gradually applied to avoid any shock load. Then, in order to raise the temperature, a test device made inside a heater was used to heat the lubricant to 75 °C with a standard rotation speed (1,200 rpm). After this temperature is obtained, the driving motor starts to drive the upper ball at a request speed. After a period of time (one hour), the heat process was stopped, then the pot was removed from the device, and the results were obtained, as for the work and testing of the behavior of the oil by the transformer device, it can be summarized in the following steps:

Preparing the electrical transformer device at the source and filling it with cooling oil (test sample).

- Connecting six thermocouples installed in different positions (4 thermocouples in the transformer body) and (2 thermocouples inside the transformer) and connected to the data recorder.
- The initial temperatures of the oil and the ambient temperature were recorded.
- The oil was heated up by operating the electric power source feeding the load.
- 5- Recording the temperature readings in different positions of the oil in the thermocouples by the data logger every period 15 minutes until the oil temperature reaches about 80°C.

3.1 Wear scar diameter

After you take out the ball and look at it and Using computer programming with good accuracy along with the use of the acquired micrograph, the length and width of the small "wear scar" and from these two dimensions are determined as the "wear scar diameter" The assumption is that the smallest The scar, the less wear occurs - the better the lubrication of the fuel sample. It is usually known that the greater the breadth of the wear scar, the weaker the abrasion. Ly, an estimate of the wear scar amplitude and, therefore, three balls were performed for any test to consider the implementation and detection of the lubrication of any experimental oil.

3.2 Friction's Torque plus factor

Certain information was obtained to re-encode the friction torque, which witnessed a rapid increase at the beginning of the test, and then, when a period of 5 to 10 minutes passed from the start of the test, it became stable and stable in the results. Likewise, for the steady-state example, the average friction torque was recorded and then the friction factor corresponding to (IP-239) was determined, as shown in the equation below

$$\mu = \frac{T\sqrt{6}}{3Wr} \quad (1)$$

Where μ = friction factor.
T = Friction torque in kg mm.
W = load exposed per kg.
r = 3.67 (area from the center of contact surface above the lower balls up to the rotating axis). [25-27] and [11] also use such a method. The friction torque as well as the friction factor was calculated automatically using a computer, and the readings were recorded automatically.

3.3 Flash temperature

The maximum flash temperature (FTP) parameter can be defined as a value used to express the (maximum) and critical temperature above which the lubricant film thickness will be loosened and broken and there will be an oil failure under certain test conditions. Under this excess temperature under certain conditions, Equation 2. From the equation, it can be seen that the FTP value depends on the applied load and WSD and one can control FTP. FTP provides little chance to break down the oily film epithelial tissue [28-34]. The large FTP rating offers great oil cooling performance:

$$FTP = \frac{W}{(WSD)^{1.4}} \quad (2)$$

Where: W= the applied load in kg
WSD= the wear scar diameter in mm.

3.4 Oil temperature

The manufacture and implementation of a prototype system (transformer) for measuring oil temperatures (cooling performance) was carried out by using thermocouples and data recorder in different places in the prototype of the cooling oil and for different times with loading and without loading, and within a period of time of (90 minutes) from the operating time of the converter.

3.5 Result and Discussions

3.6 kinematic viscosity

It is known as a measure of the internal resistance of a liquid to flow under the forces of gravity and is called as kinematic viscosity. In order to determine the viscosity, it is determined by measuring the time in seconds a viscometer that gets a column at a certain speed was used. The rotational velocity of the axis, which comes across the viscosity, can be measured after the shaft is immersed in oil and required for a constant volume of fluid to flow a known distance by gravity through a capillary tube inside the viscometer calibrated at a closely controlled temperature. This value is converted to standard units such as centistokes (cSt) or square millimeters per second and the temperature at which the viscosity test of the oil sample is to be reported. For liquids and oil, viscosity is a very important feature. The viscosity of the oil is between 12.4 and 10.1 mm2 / s at 100 °C, while the viscosity ranges between 54.16 and 46.18 mm^2 / s at 40 °C for mineral and vegetable oil respectively. Figure 9, below provides a comparison between the viscosity of vegetable (corn) oil and commercial mineral oil at 40, 75 and 100°C. Vegetable oil (corn) can have a straight line viscosity and lower viscosity for mineral oil. However, in any temperature test, the viscosity can be lower compared to 100% commercial mineral oil.

3.7 Wear scar diameter

After testing the samples of oils, an optical computer was used in addition to SEM (scanning electron microscopy). Observation was performed to determine the diameter of the erosion zone that occurred in the three balls. Average estimates of the wear scar diameter are shown in Figure 10. The oil sample information shown in the above-mentioned figure indicates that the WSD (wear scar diameter) in the corn oil (CO100) sample was less than the corrosion scar diameter in the commercial mineral oil (MO250) sample, where the scar diameter determination was measured at 375 μm for the corn oil sample and 377 μm for the mineral oil sample .

3.8 Friction Torque

After completion of the test for the samples used, the friction performance of the corn oil (CO100) sample was evaluated under 392.4 regular loads, rotation speed of 1,200 rpm, temperature of 75 °C, oil temperature within 60 minutes and a comparison with that of mineral oil sample (MO250).Figure 8 shows the results of the achieved friction torque, and it shows that the friction torque of the whole oil used is inside the current sheet. At the beginning of the test, it rises rapidly and over a period of (5 - 10 minutes), and then turns into a stable and steady state with the movement towards the final stage of the experiments. The steady-state condition of the friction torque indicates that the oil sample layer in the middle of the balls is unchanged without fracturing the oil layer. Depending on the results, it can be seen that the friction torque of the mineral oil sample (0.0651) was higher than the value of the friction torque of the corn oil sample (0.0621), as shown in Figure 11.

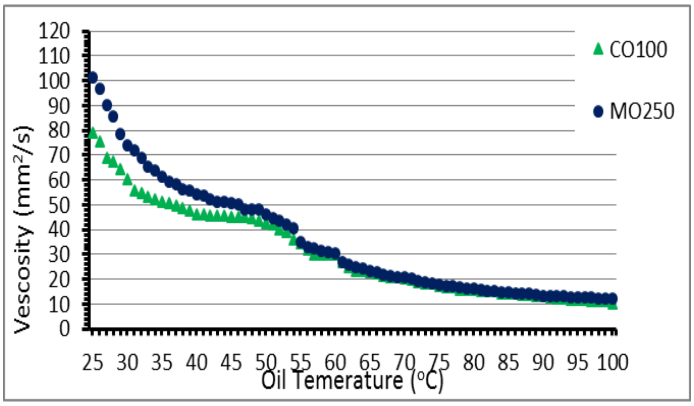

Figure 9: viscosity for the Oil samples at 40, 75 and 100°C

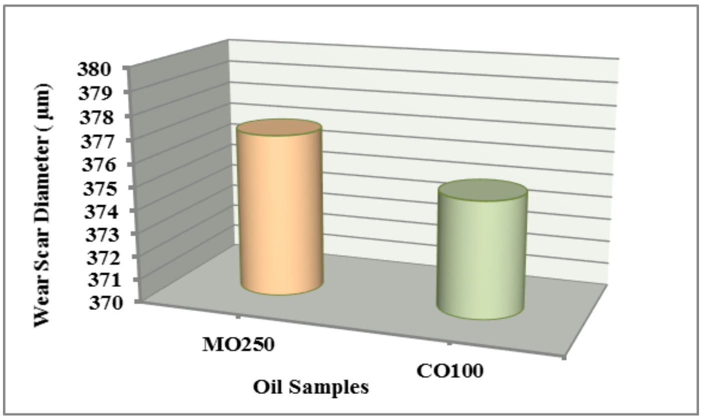

Figure 10: Wear scar diameter (µm) for the oil specimens

3.9 Friction factor

After the completion of the test and obtaining the sample results, Figure (12) shows the schematic diagram and the friction factors were determined for testing the samples of oils completely under the specified settings. It is concluded from the analysis of the plotted results that for the specified samples, the friction coefficient of the corn oil sample (CO100) was 100% lower than that of the commercial mineral oil sample. Also, it can be observed, at 392.4N for normal load of pure corn oil, the lowest coefficient of friction is (0.035207) compared to (0.036908) for mineral oil, so corn oil will give the largest lubrication capacity compared to commercial mineral liquid in laboratory .

3.10 Flash temperature parameter

Further, through the results achieved and obtained laboratory, through which it is possible to calculate in addition to the FTP drawing (gloss temperature parameter) of the two oils tested under the conditions of ASTM D4172-B as shown in Figure 13 .

Depending on the test results as shown in Figure 13, it can be observed that is, there is a slight difference in the values of the flash temperature coefficients for the biological oils (corn oil sample) and mineral (mineral oil sample) as they were 156.7 for the mineral oil sample (MO250) and 157.9 for the corn oil sample (CO100). Thus, it can be concluded that corn oil has a good level of cooling performance and also that this oil has the advantage that the corn oil fracture layer is less compared to the fracture layer of the mineral cooling oil.

3.11 Oil temperature

Figure 14, is a comparison of the temperature values of the corn oil sample and the mineral oil sample. Mineral oil (MO250) and corn oil (CO100) were offered with different loads starting from (200-1600 watts). After a period of 120 minutes from the test time, the figure clearly indicates that the oil temperature values of two samples were comparable to each other under low load (200-600 W). In addition, the highest oil temperature value was obtained .

The sample was for mineral oil (30.68 ° C and 50.91 ° C below 200 and 1,800 W, respectively, and 29.12 and 43.93 under 200 and 1,600 W, respectively). As shown in the drawing, it can be pointed out that the fatty acids in vegetable oil (corn oil) lead to lower oil temperature values. In Figure 15, a relationship between the oil temperature of the upper and lower surfaces inside the transformer is shown with the time and the projected load under the same operating conditions. It was noticed that the temperature of the vegetable oil is lower than the mineral oil due to the presence of fatty acids.

In Figure 16, a relationship is shown between the amount of heat driven from the transformer with the applied load in the same operating conditions. It was noticed that the lost heat in vegetable oil is less than mineral oil, and thus the coils will be preserved. In Figure 17, a relationship is shown between the electric current of a transformer with time at the same operating conditions. It was noted that the electrical current in vegetable oil is less than that of mineral oil, and therefore the transformer is not affected when overloading during peak time.

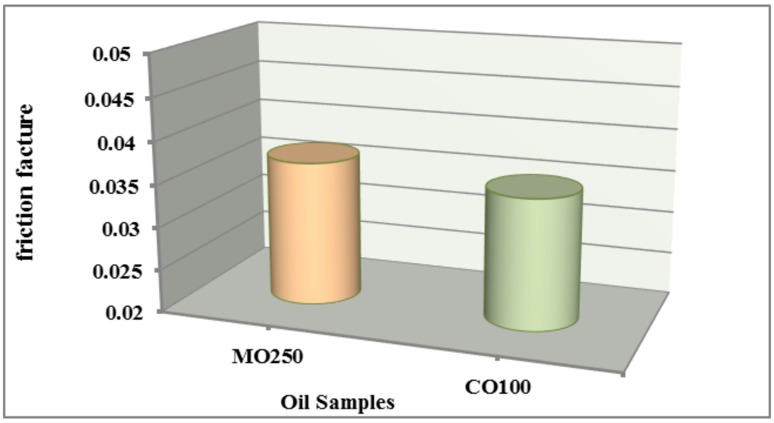

Figure 11: Friction torque of the oil specimens

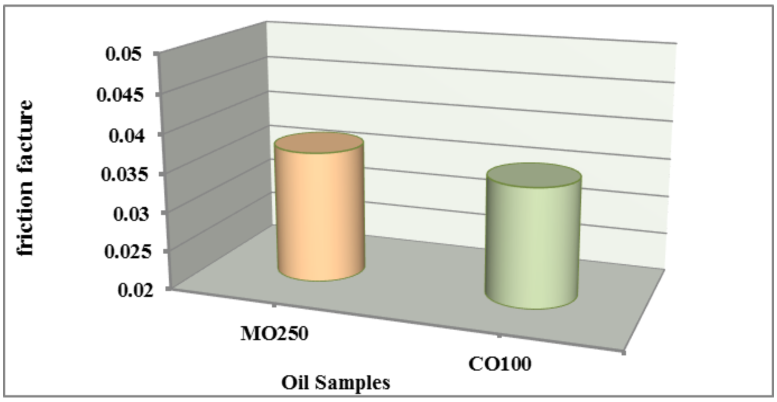

Figure 12: Friction factor under different normal load

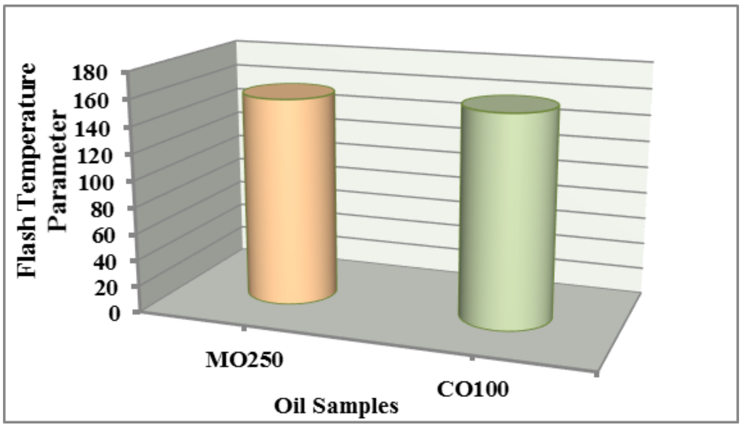

Figure 13: Flash temperature parameter for the oil samples

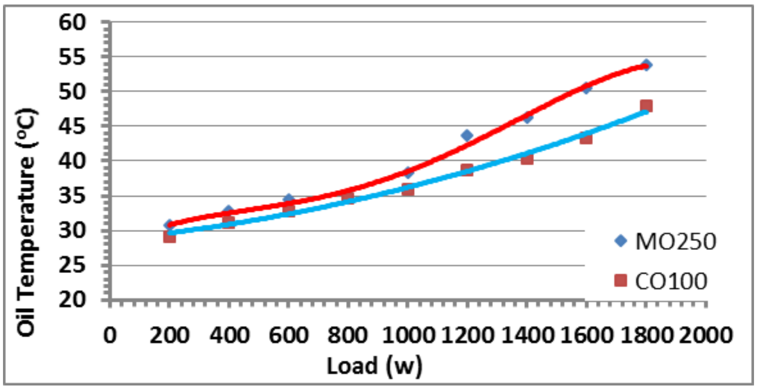

Figure 14: oil temperature under different load for oil samples

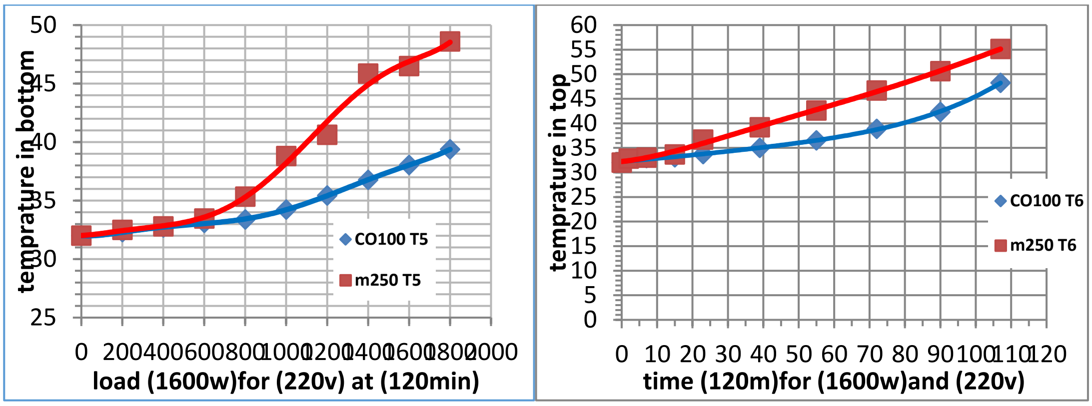

Figure 15: temperature oil and load and time

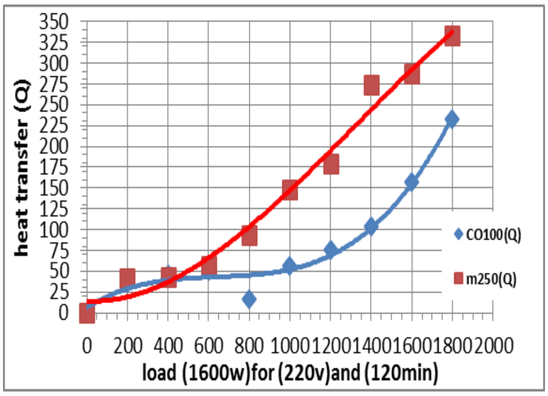

Figure 16: heat transfer and load

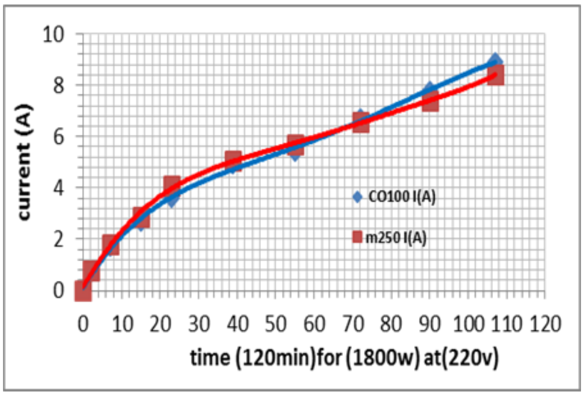

Figure 17: current transformer and time

4. Conclusions

This study shows the use of a prototype of an insulated electrical transformer, and the use of a four-ball device to find out the cooling performance characteristics of bio-oil (corn oil) in electrical transformers. The experiment's times were set to 120 minutes in the prototype (switch) and the time control on the four ball machine was set for 60 minutes, and the rotation speed of the upper ball in the four ball machine was 1,200 rpm. A variety of electrical loads, ranging from 200 to 1,600 watts. The results showed that the renewable vital oil (corn oil) can be used as a successful cooling liquid in electrical transformers, because it gives satisfactory results under different electrical loads and for a long test period of time. Also, this sample is from the cooling oil (corn oil).

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

[1] S . K . Sahdev , Electrical Machines, Cambridge University Press, Nov 24, 2017 .

[2] B . L . Therja , A . K . Therja A Text Book in Electrical Technology,2, S. Chand, 2005.

[3] [M . A . Delgado , L . A . Quinchia , and C . Galegos Viscosity modification of different vegetable oil with EVA copolymer for lubricant applicants , Industrial Crops and Products, 32,1,2010,607–612.

[4] M. Nosonovsky, Oil as a lubricant in the ancient Middle East, Tribology Online, 2 , 2 , 2007, 44–49 . [Online] at Available :: https://www.jstage.jst.go.jp/article/trol/2/2/2_2_44/_article/-char/ja/ Online ISSN : 1881-2198 .ISSN-L : 1881-218X , https://doi.org/10.2474/trol.2.44

[5] M . Hassan , F . N . Ani , and S . Syahrullail , The tribological characteristics of rbd palm olein with jatropha oil blend using four-ball tribotester with different normal loads , Applied Mechanics and Materials, 819, 2016, 499-503. . https://doi.org/10.4028/www.scientific.net/AMM.819.499

[6] I . Golshokouh , S . Syahrullail , F . N . Ani , and H . H . Masjuki. Investigation of Palm Fatty Acid Distillate Oil as an Alternative to Petrochemical Based Lubricant .MPOB Journal, 7 , 1 , 2013,72-80.

[7] M . H . Jabal , A . R . Abdulmunem , and H . S . Abd , Experimental investigation of tribological characteristics and emissions with nonedible sunflower oil as a bio lubricant , Journal of the Air & Waste Management Association, 69 ,1 2019,109-118 . DOI: 10.1080/10962247.2018.1523070.

[8] H . I . Ahmed , X . M . Hassan , and C . A . Abdul, Performance changes for window type air-conditioner unit chemically treated to work in an industrial petrochemical environment , Engineering & Technology Journal, 29 , 2011, 430-447.

[9] W . B . W . Nik , F . N . Ani , and H . H . Masjuki , Thermal stability evaluation of palm oil as energy transport media , Energy Conservation and Management, 46 , 13-14 , 2005, 2198-2215.

https://www.sciencedirect.com/science/article/abs/pii/S0196890404002456

[10] S . Syahrullail , K . Nakanishi , and S . Kamitani . Investigation of the effects of frictional constraint with application of palm olein oil lubricant and paraffin mineral oil lubricant on plastic deformation by plane strain extrusion , Journal of Japanese Society of Tribologists , 50,12,2005,877–885.

[11] C . T . Ing , A. K. M. Rafiq , Y. Azli , and S . Syahrullail ,The effect of temperature on the tribological behavior of RBD palm stearin, Tribology Transactions, 55 , 5 , 2012, 539–548.. https://doi.org/10.1080/10402004.2012.680176

[12] M . Hassan , S . Syahrullail , and F . N . Ani . The tribological characteristics of the cactus and mineral oil blends using four-ball tribotester , . Jurnal Teknologi, Progress in Energy and Thermofluids Sciences , 78 , 9-2 , 2016, 33-38 . doi: https://doi.org/10.11113/jt.v78.9652

[13] M . H . Jabal , F . N . Ani , and S . Syahrullail . The Tribological Characteristic of the Blends of RBD Palm Olein with Mineral Oil using Four-ball Tribotester, Jurnal Teknologi, 69 , 2014,11-14.

doi: https://doi.org/10.11113/jt.v69.3232

[14] M . A . Maleque , H . H . Masjuki , and A.S.M.A. Haseeb, Effect of mechanical factors on tribological properties **4** of palm oil methyl ester blended lubricant .Wear, 239 , 1 ,2000,117–125. . doi.org/10.1016/S0043-1648(00)00319-7

[15] M . H . Jabal , M . Z . Khalefa , Tribological Characteristics Evaluation of Mustard Oil Blends . Journal of Engineering,. 24 , 3 , 2018,1-12. doi: 10.31026/j.eng.2018.03.01.

[16] M . H . Jabal , F. N . Ani , and S . S . Syahrullail , Tribological features of refined, bleached and deodourised (RBD) palm olein blends with mineral oil . Jurnal Mekanikal,38,2,2015 .

https://jurnalmekanikal.utm.my/index.php/jurnalmekanikal/article/view/21.

[17] A . R . Abdulmunem , M . H . Jabal , P. M . Samin , H . A . Rahman , and H. A. Hussien , Analysis of Energy and Exergy for the Flat Plate Solar Air Collector with Longitudinal Fins Embedded in Paraffin Wax Located in Baghdad Center .37 , 4 , 219,1180-1186. Journal homepage: http://iieta. org/journals/ijht,

[18] H . S . Abd , A . R . Abdulmunem , M . H . Jabal , P. M . Samin , and H. A. Rahman . Working Features Evaluation of the Diesel Engine Lubricated with Blends of Renewable Corn Oil and Carbon Nanotubes J. Mech. Eng. Res. Develop , 43 , 2 , 2020,384-395.

[19] M . H . Jabal , M . Z . Khlefia , I . S . Ahmed ,and H . D . Salman , Performance Features Of The Sunflower Seeds Oil As A Hydraulic Bio Fluid Under Various Normal Loads . Journal Teknologi, 82 . 2 , , 2020 .

:doi.org/10.11113/jt.v82.13354 .

[20] M . H . Jabal , H . S. Abd , A . A . Gaddoa , I . F. Kadhim , S . Samion , A . S . Shajar , and A . A. Hardan , Palm Olein with Jatropha Curcas Oil Blend as a Renewable Bio-Fluid, IOP Conference Series: Materials Science and Engineering , 765,. 1, 2020,p. 012025.

[21] A . R. . Abdulmunem , M . H . Jabal , and H . S . Abd , IC-Engine performance using MWCNT Dispersed in non-edible sunflower oil as Bio lubricant: Experimental Investigation . International Journal of mechanical Engineering and Technology (IJMET) . 9, 13, 2018,1071–1082. [online] at Available : http://www.iae ISSN Print: 0976-6340 and ISSN

[22] M . H. Jabal , M . Z . Khlefia , and A. R. Abdulmunem Tribological Performance Of Mustard Seeds Oil Under Different Loads Using Pin-On-Disk Tribotester . the iraqi journal for mechanical and materials engineering , 18, 4 , 2018,527-537.

[23] M. Hassan , F.N. Ani , and S. Syahrullail . Tribological Performance of Refined, Bleached and Deodorised Palm Olein Blends Bio-lubricants . Journal of Oil Palm Research , 28 , 4 ,2016, 510-519 .

[24] H . H . Masjuki , M.A. Maleque , Investigation of the anti-wear characteristics of palm oil methyl ester (POME) contaminated with lube oil using a Four-ball machine of IP239 standard . Wear, , 206 , 1-2 , 1997,179-186.

[25] F. A. Fattah , M. M. Ariff, J. M .Hassan , and A. F. Nasir . The Tribological Characteristics of Rubber Seed Oil With Mineral Oil Blends .Malaysian Journal of Industrial Technology (MJIT). 2 , 2 , 2017,2462-2540 .

[26] M . Hassan , F. N. Ani and S. Syahrullail. Tribological Features of Refined, Deodorized, and Bleached Palm Olein with Mineral Oil Blend .Tribology Transactions, 59 , 4 , 2016, 671-678. https://doi.org/10.1080/10402004.2015.1107928 .

[27] A. Hussain , S. Mehdi , A. Ali , M. Adeel , M . Jabal , and F. Ani , Investigation of tribological characteristics of castor oil with mineral oil blends . Journal Of Engineering And Applied Sciences, , 37 , 1 , 30 June , 2018 . https:// doi.org/https: //doi.org /10.25211 /jeas.v37i1.2688.

[28] M. H. Jabal, E. O. Hassoun, A. R. Abdulmunem, and F. N. Ani . Experimental Investigation Of The Neat Rubber Seed Oil As A Hydraulic Fluid Using Four-Ball Tribotester .Journal of Engineering Science and Technology , 14 , 5 , 2019,2670 – 2680.

[29] Electrical Insulating Oil Test Lab , https://www.nepco.com.jo/intel/oil_lab_ar.aspx

[30] J. Dofan, Study On Thermal Model For Calculating Transformer Hot Spot Temperature, Faculty Of Electrical & Electronic Engineering, University Tun Hussein Onn Malaysia (UTHM) . PhD diss , Thesis, May, 2011.

[31] L . L . Grigsby, The electric power engineering handbook Power Systems, Taylor &Francis group , Third Edition , London, New York , 2012.

[32] R . M . Del Vecchio , B . Poulin , P . T. Feghali , D . M . Shah, and R . Ahuja . Transformer design principles, Taylor &Francis group , third edition , London , new York , 2017. https://doi.org/10.1201/9781315155920

[33] The State Company for Electrical and Electronic Industries, AL-Wazyria, Baghdad, 2021.

[34] **M** . H. Jabal, A. Abdulmunem , and H . Abd, As a potential hydraulic fluid: corn oil behavior characteristics examination, Journal of Thermal Engineering, Special Issue 13: 2nd International Conference (ICRESE -2020), India. 7, 2 , 2021, 215-221. doi: 10.18186/thermal.871628,