JOURNAL OF PURE AND APPLIED MICROBIOLOGY, May 2015. Vol. **9**(Spl. Edn. 1), p. 645-651

Composite Treatment and Chemical Analysis of Various Oils for Energy Efficient Operation in Transformer

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(Received: 15 January 2015; accepted: 06 February 2015)

The energy demand of world is mostly based on petroleum products. Mineral oil is a critical component in Transformer. Oil plays a promistic role for life of Transformer. Insulation is one of the critical parameter in inside of the Transformer. A major problem in any country is availability of Transformer oil. Hence substitute of mineral oil is more important in Transformer. In this work, various oils are applied in transformer safely and the performance of oil is investigated. This work mainly focuses on a comparative analysis of break down voltage, viscosity, fire point, flash point and Efficiency of various oil and mineral oil. It should be verified and compared with mineral oil. It also explains the efficiency of these oils. The ac breakdown strength of these three oils at different temperatures was also investigated. The above properties of three oils are implemented in prototype transformer and the efficiencies of the transformer are calculated.

Key words: Transformer oils, Furan compound, Property, Efficiency, Energy savings.

Transformer is a most critical component in transmission and distribution network in power system[1]. Insulation used in transformer is of solid and liquid insulation. Insulating oil (transformer oil) having high electrical insulation and heat exchange medium in between windings of transformers. Transformer oil consists of better electrical, physical and chemical characteristics. Most of the transformer is failure due to dielectric insulation problems[2].

High energy efficient transformer oil is necessary for increasing the efficiency of transformer at different voltage level in power system. The work has been made to compare the new insulating medium with better insulating properties[3]. The conventional transformer oils (mineral oils) are normally non-biodegradable. It consists of contaminated soil and water. It leads to disturb the plantation and other organisms. The mineral oils were extracted from petroleum products. The source of mineral oil is very limited since it is a non-renewable energy source. In general natural ester in mineral oil is fire safety, environment, and insulation ageing advantages. Hence it is to be suitable for transformer insulation system[4]. In this work, an effort is taken to find the alternative source and compare the energy efficient levels of different oils in same transformer.

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Experimental Details

Measurement of Breakdown voltage

Breakdown voltage and oil performance are determined by Presence of bubbles, Solid particles, Acidity and Moisture pressure. The following samples are taken for determining the performance.

1. Ideal Transformer oil (Mineral Oil).
2. Vegetable Oils
   a) Rice bran oil
   b) Rice bran oil with Furan compound (Hexagonal Furan Nitrate)

As per IEC 60156 standard, the breakdown voltages of each samples were determined at room temperature by the above oil test kit. The capacity of oil test kit is 60 KV. It is shown in Figures 1and 2.

It consists of standard oil test cup with spherical electrode. The electrodes gap distance was maintained at 2.5 mm during measurement. First oil test cup was rinsed with the given sample for measuring the breakdown voltage. Then it was filled with the sample whose breakdown voltage is to be measured (Table1). The sample was filled up to the height not less than 40mm from the top of the electrode.

Control knob in test kit is used to vary the supply voltage at the rate of 2kV/s. The measurement of breakdown voltage of sample oil was carried out 5 to 6 times for all samples. The average of these values was taken as breakdown voltage of that sample. Various oils are heated with 110°C, for 5h, 10h, 15h and 20h, for measuring the breakdown voltage (Table 2). Corresponding graph is shown in Figure. 3. From the observation of Table 2, ac breakdown strength of Rice bran oil with Furan compound is much higher than mineral oil.

Measurement of Flash point and Fire point

A physical property of the transformer oil is flash point and fire point. Its temperature is determined at which, the same oil may ignite the fire and flash. The flash point is the lowest temperature. It means the oil can vaporize to form a mixture of ignition in air. The fire point is the highest temperature at which the formed vapour is ready

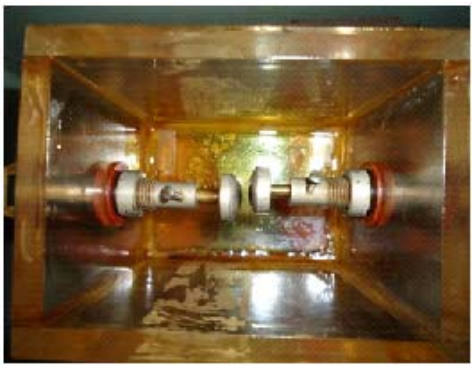

Fig. 1. Oil test cup – top view

Fig. 2. Oil test kit – front view

Table 1. Sample Taken for Investigations

Samples	Combination of samples
Sample 1	Ideal Transformer oil
	Transformer oil with 110°C, 5h
	Transformer oil with 110°C, 10h
	Transformer oil with 110°C, 15h
	Transformer oil with 110°C, 20h
Sample 2	Ideal Rice bran oil
	Rice bran oil with 110°C, 5h
	Rice bran oil with 110°C, 10h
	Rice bran oil with 110°C, 15h
	Rice bran oil with 110°C, 20h
Sample 3	Rice bran oil with Hexagonal Furan Nitrate
	Rice bran oil with Furan compound with 110°C, 5h
	Rice bran oil with Furan compound with 110°C, 10h
	Rice bran oil with Furan compound with 110°C, 15h
	Rice bran oil with Furan compound with 110°C, 20h

Table 2. Breakdown Voltage of Oils

Samples	Breakdown Voltage (kV)
Ideal Transformer oil	36.8
Transformer oil with 110°C, 5h	30.2
Transformer oil with 110°C, 10h	26.4
Transformer oil with 110°C, 15h	22.8
Transformer oil with 110°C, 20h	17.4
Ideal Rice bran oil	30.4
Rice bran oil with 110°C, 5h	26.6
Rice bran oil with 110°C, 10h	24.8
Rice bran oil with 110°C, 15h	20.2
Rice bran oil with 110°C, 20h	16.8
Rice bran oil with Hexagonal Furan Nitrate	38.4
Rice bran oil with Furan compound with 110°C, 5h	32.4
Rice bran oil with Furan compound with 110°C, 10h	30.8
Rice bran oil with Furan compound with 110°C, 15h	28.2
Rice bran oil with Furan compound with 110°C, 20h	24.6

to burn[5, 7]. Comparison between mineral and vegetable oils with applications and environmental advantages are already described by some researchers[8, 10].The flash point and the fire point were measured as per the ASTM D 93 Standard at room temperature[11,12] by using Pensky Martin Flash point Apparatus. The Apparatus is a closed cup tester (Fig. 4).

Sample oil was filled in brass test cup and the temperature was increased. The flash point with vapour formation and temporary fire on the oil surface was measured with corresponding temperature. Similarly, the temperature corresponding to the fire point was measured with continuous fire on the oil surface when a small test flame was directed into the sample.

The comparison of flash point and fire point of various oils are shown in Figures 5 and 6. The flash Point and fire Point of the mineral oil, vegetable oil and vegetable oil with Furan compound samples are given in Table 3.

From the observation of Table 3, the flash point and fire point of Mineral oil is less than the flash point and fire point of Vegetable oils.

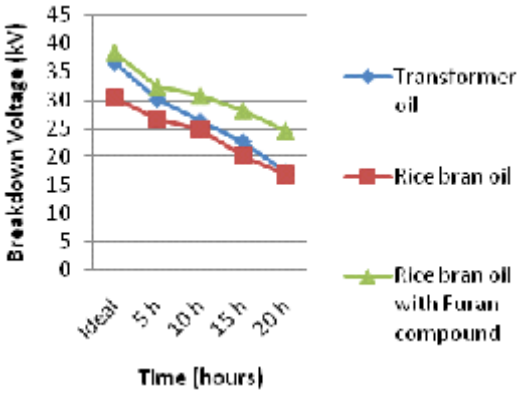

Fig. 3. Breakdown voltages of various oils

Table 3. Flash point and Fire point of Oils

Samples	Flash Point (°C)	Fire Point (°C)
Ideal Transformer oil	259	273
Transformer oil with 110°C, 5h	204	244
Transformer oil with 110°C, 10h	189	197
Transformer oil with 110°C, 15h	167	173
Transformer oil with 110°C, 20h	132	144
Ideal Rice bran oil	253	267
Rice bran oil with 110°C, 5h	198	218
Rice bran oil with 110°C, 10h	183	191
Rice bran oil with 110°C, 15h	161	167
Rice bran oil with 110°C, 20h	126	138
Rice bran oil with Hexagonal Furan Nitrate	265	282
Rice bran oil with Furan compound with 110°C, 5h	212	250
Rice bran oil with Furan compound with 110°C, 10h	194	206
Rice bran oil with Furan compound with 110°C, 15h	178	194
Rice bran oil with Furan compound with 110°C, 20h	140	156

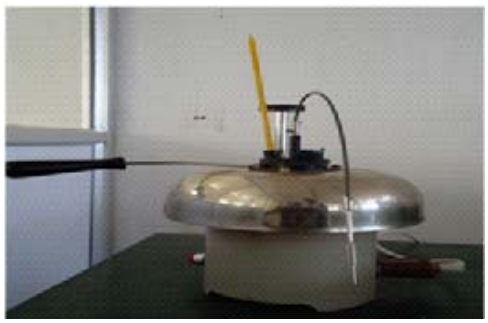

Fig. 4. Pensky martin flash point apparatus

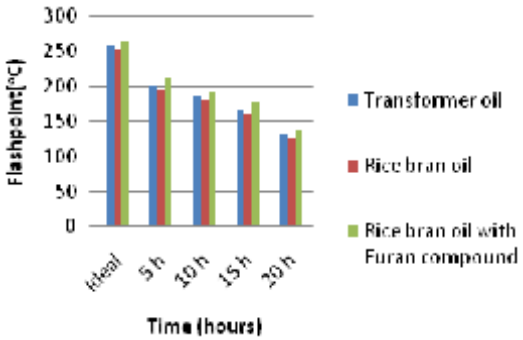

Fig. 5. Flash point of various oils

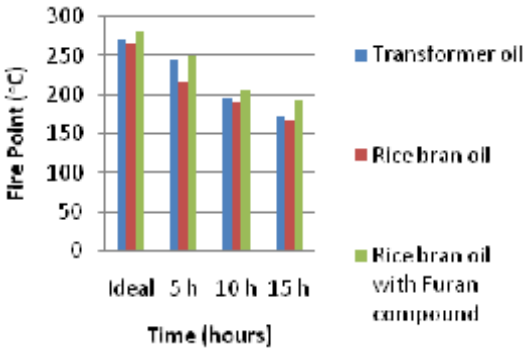

Fig. 6. Fire point of various oils

Measurement of Viscosity

Viscosity of oil is one of the important factors in transformer. The transformer oil should have moderate viscosity for cooling the windings and tank with free circulation. Viscosity of the oil also depends upon the temperature [13]. The fluid with low viscosity is easily moved without any resistance.

As per the ASTM D445 standard, the viscosity of all oils was measured at room temperature by using redwood viscometer (Figure. 7). The sample oil was filled in silver plated oil cup. Ball valve (orifice) in viscometer is used to allow the flow of sample and test beaker in viscometer which is used for collecting the sample. Quantity of sample oil in beaker is 50 ml. The viscosity of the mineral oil and vegetable oil samples are given in Table 4.

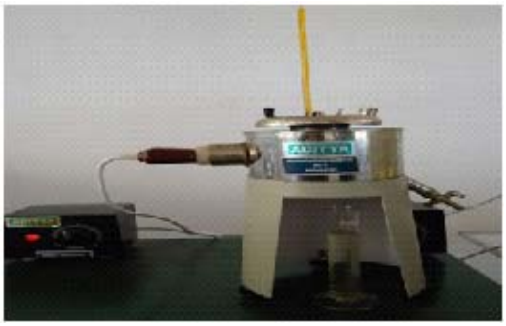

Fig. 7. Redwood viscometer

Fig. 8. Prototype1KVA Transformer

Table 4. Viscosity of Oils in CS

Temp	30°C	40°C	50 °C	60°C	70°C	80°C	90°C
Ideal M.O	36	29	23	17	15	13	12
M.O110°C, 5h	30	26	21	16	14	12	11
M.O110°C 10h	28	24	19	14	12	11	10
M.O110°C, 15h	25	21	17	13	11.9	10.7	9.5
M.O110°C 20h	23	19	16	12	11	10	9
Ideal R.B.O	75	56	47	35	30	24	22
R.B.O 110°C, 5h	63	54	43	37	31	25	20
R.B.O 110°C, 10h	52	44	36	29	25	21	16
R.B.O 110°C, 15h	45	38	31	26	22	18	12
R.B.O 110°C, 20h	32	28	23	18	15	12	10
R.B.O with F.C.	119	114	55	39	34	30	24
R.B.O with F.C. 110°C, 5h	110	77	54	38	33	29	22
R.B.O with F.C. 110°C, 10h	95	74	52	36	30	24	20
R.B.O with F.C. 110°C, 15h	84	68	50	35	28	20	18
R.B.O with F.C. 110°C, 20h	77	62	42	28	24	19	15

Table 5. Observation of Resistive Load using Mineral Oil

Parameters	Voltage Level			Temperature(°C)		
	No Load	Half Load	Full Load	No Load	Half Load	Full Load
Mineral Oil	208	205	198	32	78	110
Rice bran oil	213	208	200	32	74	110
Rice bran oil with Hexagonal Furan Nitrate	218	214	205	32	70	102

Measurement of Power and Efficiency

Efficiency of Transformer is most important in power system. In general, efficiency of transformer is higher than any rotating machine, since transformer is a static electrical apparatus. However the efficiency of transformer is tested under various liquid insulating oils under various load conditions. The various load tests were conducted on Prototype 1 KVA transformer. (Figures 8 and 9).

Measurement of Voltage and Temperature

In this work, test oil was poured into the transformer. The winding was completely immersed in the oil and the supply is applied to the transformer. Electrical load is connected across the output of prototype transformer. The load voltage and current were measured at half and full load capacity with time. In the same way, efficiency testing methodology was continuing for different liquid insulations. From the observation of testing,

Fig. 9. Windings of 1KVA Prototype Transformer

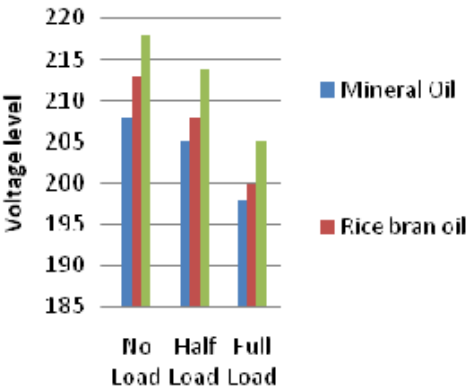

Fig. 10. Comparison of voltage at different oils under different load condition

Table 6. Comparative Efficiency Analysis of various Oils

S.No	Oils	Load	Input(Watts)	Output (Watts)	Efficiency %
1.	Mineral Oil	Half Load	400	330	82.50
		Full Load	675	606	89.78
2.	Rice bran oil	Half Load	460	368	80.00
		Full Load	710	612	86.19
3.	Rice bran oil with	Half Load	392	342	87.24
	Hexagonal Furan Nitrate	Full Load	676	620	91.72

Table 7. Comparative Analysis for Mineral and Vegetable Oils

Parameters	Mineral Oil	VegetableOil (Rice bran oil)	Rice bran oil with Hexagonal Furan Nitrate
Breakdown Voltage	36.8 KV	30.4KV	38.4 KV
viscosity 30°C	36 Cst	75 Cst	119 Cst
60°C	17 Cst	35 Cst	39 Cst
90°C	12 Cst	22Cst	24 Cst
Flash Point	259°C	253°C	265°C
Fire Point	273°C	267°C	282°C
Temperature(°C)	110 °C	110 °C	102 °C
Efficiency % at Full load	89.78 %	86.19 %	91.72 %
Energy Savings	Satisfactory	Good	Very good

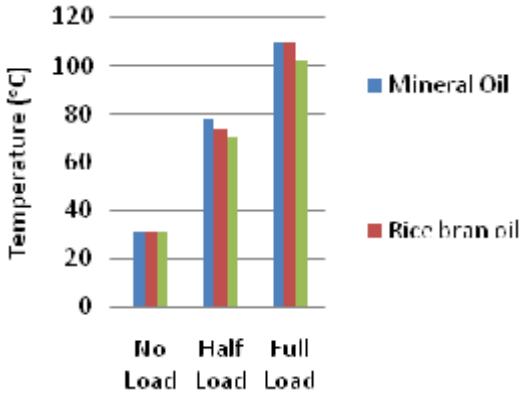

Fig . 11. Comparison of temperature at different oils under different load condition

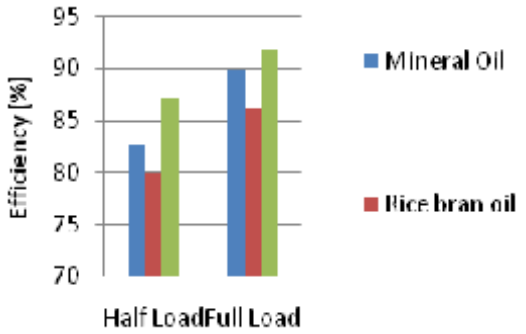

Fig. 12. Comparative Efficiency Analysis of various oils

the suitable oil from test oils is found out for improving the efficiency of transformer.

Power taken by prototype transformer is proportional between the current flowing (Amps), the voltage across the resistor (Volts) and the value of the resistor itself (Ohms). The relationship stands regardless of whether alternating current or direct current is used. Power and temperature of various oils in transformer at different load condition is tabulated in Table 5. From the observation of Table 5, voltage in Rice bran oil with Hexagonal Furan Nitrate is higher than other two oils (Figure. 10) and temperature of Rice bran oil with Hexagonal Furan Nitrate is lower than other two oils (Figure. 11).

Comparative Analysis of Oils and Conclusion

Calculation of Efficiency

The efficiency of the transformer mostly depends upon the losses like iron and copper losses. Core loss depends upon the supply frequency and flux density in the core. Copper losses occur in Primary and Secondary windings[14]. Therefore, little energy is lost in the form of heat through the windings. [15].

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

(i) Input Power = Primary winding wattmeter

(ii) Output Power =Secondary winding wattmeter.

A comparative study of the Viscosity, Breakdown voltage, Flash point, Fire point and Efficiency of vegetable oil and mineral oil are mostly based (Figure.12) on energy consumption. These mineral and vegetable oil parameters are tested by different test equipments like Oil test kit, Pensky martin flash point apparatus, Redwood viscometer and load test.

From the observation of the Tables 6 and 7, the efficiency of Transformer with Rice bran oil with Furan Compound is higher than the efficiency of Transformer with Mineral oil. From the review of above parameters, a loss of Transformer is sufficiently decreased at Rice bran oil with Furan Compound present in the transformer oil. Hence the efficiency of the transformer is also increased. These results may add credence that vegetable oil with Furan Compound (Hexagonal Furan Nitrate) can be used in transformer safely.

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