Characteristics of Natural Ester Oil Exposed with Ultrasonic Sound Waves

Rethish Kumar C, Willjuice Iruthayarajan M, Bakrutheen M

Abstract: ***In the present scenario of development towards sustainable alternate oil insulation for transformers, vegetable oils based natural esters have impressed as a potential substitute to transformer oil liquid insulation among many research people. Even though natural esters have possessed better electrical characteristics as liquid insulation, they have some drawbacks related to viscous nature, which will affect the flowing nature. This work aims to develop low viscous natural ester oil for the application as liquid insulation with exposing the natural esters to ultrasonic sound waves. Ultrasonic sound waves are exposed to natural esters for duration of 1 hour and 2 hours. The impact of ultrasonic sound waves on the viscosities of natural ester oil samples are analyzed before and after the exposure treatment process. Further other characteristics such as breakdown voltage (BDV), flash point, fire point, pour point, and density of natural ester oil samples are measured to identify the outcome of ultrasonic treatment. From this investigation results, it is found that the ultrasonic sound waves have created an positive results with reduction in the viscosity and alteration in other characteristics of natural ester oil samples.***

Keywords**:** ***Breakdown Voltage (BDV), Flash Point, Liquid Insulation, Pour Point, Transformer, Ultrasonic Sound Wave, Vegetable Oil, Viscosity***

I. INTRODUCTION

In the process of transferring power to the consumers from power generating station, transformer plays important part in the power system network. Insulation material used in transformer is major influential factor in determining the life of transformer. Along with solid insulation, liquid insulation plays enormous role in the proper working of a power transformer by offering effective cooling process and insulation. Thus, the dependability of a transformer is primarily determined by condition of insulation used in it. Mineral oil is used in oil filled transformer as liquid insulation due to its splendid dielectric and cooling properties.

With concern related to mineral oil over the period of many years from its inception, the researchers are working towards finding suitable alternate insulating medium. The development of alternate liquid insulation is focused towards finding the suitable replacement oil which has similar insulating characteristics and also does not possess the drawbacks of mineral oil based liquid insulation. With the above said aspects, many researchers are focusing vegetable oil as a viable solution to the issues with mineral oil since late 90s. The preference for vegetable oil is due to natural products, environmental friendly characteristics, huge of availability of resources, safety and health aspects, etc. Vegetable oil based natural ester oil has the potential to be a suitable contender to mineral oil based on its properties, resource, cost, etc. However, some aspects on technical background have to be overcame which are preventing the deployment of vegetable oil based natural esters as liquid insulation. Some of them are their higher value viscosity characteristics, pour point and permittivity, lower oxidation stability, etc.

The presence of glycerol with three fatty acid molecule in vegetable oil based natural ester samples are determining the behavior of oil samples and impacting the overall properties of oil. The flow related properties such as viscosity and pour point have the decisive role in designing and further impacting the cooling operation of transformers. By comparing the standard values, the values of viscosity and pour point are much higher than expected values.

For the natural ester oil filled transformers, working life is also longer because of its wonderful heat dissipating capacity if the viscosity values of natural ester based oil insulation are reduced. The lower viscosity of insulating fluid could be effectively assisted the flow of oil with cool heated windings and surfaces inside the transformers while working. The viscosity of the oil is reduced in many ways such as thermal cracking, blending process, trancertification process etc. Also another one method employed in the decreasing the viscosity of crude petroleum oil is ultrasonic sound wave treatment process. Among above said methods, ultrasonic sound wave treatment has give better results and is an easiest process.

In this proposed work, with the aim of developing vegetable oil based natural ester liquid insulation with reduced viscosity, analysis on natural ester oils is carried out with exposing the ultrasonic waves of the 100 W power and 30 kHz frequency 100W for two different exposure duration of 1 hour and 2 hour. The impact of the process is investigated with the measurement of the properties of oil such as viscosity, breakdown voltage, flash point, pour point, and density as per specified standards before and after the ultrasonic treatment process with ultrasonic waves.

Revised Manuscript Received on April 15, 2020.

***** Correspondence Author

Rethish Kumar C* is currently pursuing final year master degree program in high voltage engineering in National Engineering College, K.R. Nagar, Kovilpatti, India. E-mail: rethish810@gmail.com

Dr. Willjuice Iruthayarajan M is currently working as a Professor& Head in the Department of Electrical and Electronics Engineering in National Engineering College, K.R. Nagar, Kovilpatti, India. E-mail: m.willjuice@gmaill.com

Mr. Bakrutheen M is currently working as a Assistant Professor (Senior Grade) in the Department of Electrical and Electronics Engineering in National Engineering College, K.R. Nagar, Kovilpatti, India. E-mail: bakrutheenme@gmaill.com

II. SAMPLE PREPARATION DESCRIPTIONS

In this section, sample selections and ultrasonic treatment process are discussed.

A. Oil Sample Selection

For this investigation, it is proposed to study three different vegetable oil samples. The selected oil sample descriptions are listed in Table 1. As per the guidance of CIGRE WG's Study Committee Report WG12.17, selected oil samples are preprocessed with removal of suspended particles present in oil. Further the excess moisture present in the oil samples is removed with the drying treatment process. The processed vegetable oil samples are used for the further investigation purposes.

TABLE 1 OIL SAMPLE DESCRIPTIONS

Sample No	Acronym	Oil Sample Details
Sample 1	PO	Palm Oil
Sample 2	PNO	Peanut Oil
Sample 3	SO	Sesame Oil

B. Ultrasonic Treatment Process

The 500 ml of oil samples are taken in beaker and placed in the tub with water bath in the ultrasonicator setup which is capable of generating ultrasonic sound waves with power of 100W and frequency of 30 kHz. The oil base fluids are exposed to ultrasonic sound wave for the proposed time of 1 hour and 2 hour at room temperature. The representation of treatment setup is given in Fig. 1.

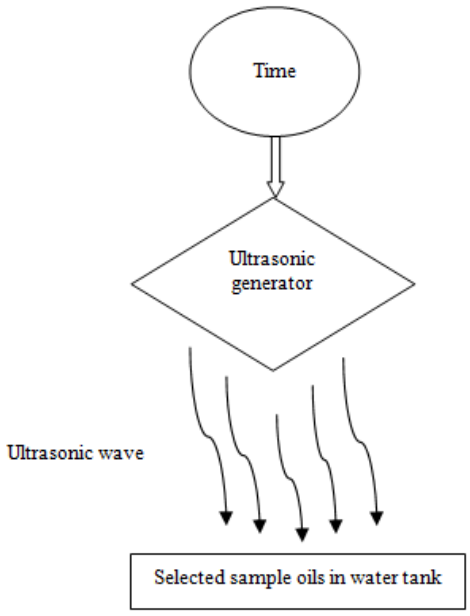

Fig. 1. Ultrasonic treatment process

III. EXPERIMENTATION PROCESS

In this proposed work, the properties associated with flow nature, electrical characteristics and thermal behavior are measured. For ensuring the impact of ultrasonic sound waves on the properties of oil samples, the values of characteristics of vegetable oil samples are measured as per the international standards which are given in Table 2.

TABLE 2 MEASUREMENT OF PROPERTIES OF OIL SAMPLES

Parameters	Standard	Method/ Equipment
Viscosity (cSt)	ASTM D445	Redwood viscometer
Breakdown voltage (kV)	IEC 60156	Breakdown voltage kit
Flash point and Fire point (^oC)	ASTM D93	Pensky martin closed cup method
Pour point (^oC)	ASTM D97	Pour Point Kit
Density (kg/cm^3)	ASTMD1217	Digital Densometer

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The properties of vegetable oil samples are measured as per the standard procedure before and after ultrasonic treatment process.

A. Properties of Oil Samples before Ultrasonic Treatment

The properties of natural ester oil samples before ultrasonic treatment process are listed in Table 3.

TABLE 3 PROPERTIES OF OIL SAMPLE BEFORE TREATMENT

Properties	Samples		
	CGNO	RGNO	CGO
Viscosity (cSt)	182.78	168.45	92.59
Breakdown voltage (kV)	35	25	30
Flash point (°C)	310	320	315
Fire point (°C)	325	330	325
Pour point (°C)	+5	-8	-12
Density (kg/cm^3)	0.903	0.906	0.901

From the results, it is inferred the following observations with the measurement of properties of oil samples before treatment.

- **Viscosity**: The maximum permissible value for viscosity value of natural ester oil is 50 cSt. From the above investigation it was observed that all the oil samples have the higher value than the specified range.
- **Breakdown voltage**: In the analysis of breakdown voltage property of natural ester, the palm oil and sesame oil samples have the better minimum breakdown voltage between 30 - 35 kV except the peanut oil.
- **Flash point and Fire point**: As per IEEE Guide, natural esters should have smallest flash point and fire point temperatures of 275°C and 295°C, whereas the peanut oil and sesame oil have a good of flash point when compared to palm oil based oil sample.
- **Pour point:** As per IEEE Guide, the needed pour point temperature of natural ester oil is -10°C. From the above investigation it was found the investigated ester oil has the pour point range from +5 to -12°C.

- **Density:** As per IEEE standard Guide, the mentionedvalue of density is 0.96 g/cm^3.All the naturalester oil has density value lower than the specified value.

For improving the flow characteristics, viscosity has to be reduced with some techniques. In this work, ultrasonic treatment with exposure to ultrasonic sound wave is proposed as the viscosity reduction technique.

B. Properties of Oil Samples after Ultrasonic Treatment

The values of characteristics of ultrasonic treated vegetable oil samples are given in Table 4 and 5 respectively for exposure duration of 1 hour and 2 hour.

TABLE 4 PROPERTIES OF OIL SAMPLES AFTER 1 HOUR TREATMENT

Properties	Samples		
	CGNO	RGNO	CGO
Viscosity (cSt)	82.66	100.95	72.52
Breakdown voltage (kV)	38	30	34
Flash point (°C)	320	325	320
Fire point (°C)	335	340	330
Pour point (°C)	+2	-2	-14
Density (kg/cm³)	0.902	0.905	0.900

TABLE 5 PROPERTIES OF OIL SAMPLES AFTER 2 HOUR TREATMENT

Properties	Samples		
	CGNO	RGNO	CGO
Viscosity (cSt)	181.85	166.54	91.19
Breakdown voltage (kV)	28	27	20
Flash point (°C)	315	325	320
Fire point (°C)	320	335	325
Pour point (°C)	+4	-5	-13
Density (kg/cm³)	0.903	0.904	0.900

- From the results after ultrasonic treatment of natural esters oil samples, it is inferred that the all the properties have changed from its original value after treatment process.
- The 1 hour treatment results in the expected result of reducing viscosity. But the viscosity is increased after 2 hour treatment which may be due to the degradation of oil sample with increase in exposure duration.
- Similarly breakdown voltage, flash point and fire point temperatures have shown increment and decrement patterns with the exposure time of 1 hour and 2 hour.
- Pour point is reduced as increase in the exposure duration.
- The density value remains at more or less same values even after treatment process.

The percentage deviations in properties of natural ester oil samples from the original value after treatment process are tabulated in Table 6 and 7 respectively for 1 hour and 2 hour treatment process.

TABLE 6 DEVIATIONS IN PROPERTIES OF OIL SAMPLES AFTER 1 HOUR TREATMENT

Properties	% Deviation in properties		
	CGNO	RGNO	CGO
Viscosity	-55	-40	-22
Breakdown voltage	9	20	13
Flash point	3	2	2
Fire point	3	3	2
Pour point	-60	-75	17
Density	0	0	0

TABLE 7 DEVIATIONS IN PROPERTIES OF OIL SAMPLES AFTER 2 HOUR TREATMENT

Properties	% Deviation in properties		
	CGNO	RGNO	CGO
Viscosity	-1	-1	-2
Breakdown voltage	-20	8	-33
Flash point	2	2	2
Fire point	-2	2	0
Pour point	-20	-38	8
Density	0	0	0

V. CONCLUSION

In present scenario, the research world is hugely witnessing the shifting from the mineral oil that are depicting in resource and environment unfriendly into vegetable oil based natural esters products that are renewable and environmentally friendly. In this work presented in work, a research attempt has been made to develop and characterize a low viscous insulating fluid with natural esters with ultrasonic treatment process. The ultrasonic sound wave treatment method is able to reduce the viscosity and have impact other properties of selected oil samples. These results have shown the positive outcome with the investigation on ultrasonic sound wave effect on properties of natural ester oils. Moreover still, lots of investigations are needed before the application and generalization of the low viscosity in the transformers.

REFERENCES

1. Antônio Pontes Filho, Murilo, Luna and Célio L. Cavalcante Jr., "Oxidative Stability of Mineral Naphthenic Insulating Oils: Optimization of Commercial Antioxidants and Metal Passivators", IEEE Trans. on Dielec. and Elect. Insul., Vol. 26, No. 1, pp. 240-246, 2019.
2. Ahamad kamal, Bashir and Muhammad, "Insulating Properties of Vegetable Oils and their Blends", IEEE Conference, pp. 455-458, 2013.
3. ASTM D 445, 2011 - Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids and Calculation of Dynamic viscosity.
4. ASTM D 93, 2012 - Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester.
5. Arumugam, Sriram and Rajmohan, "Multi-Response Optimization of Epoxidation Process Parameters of Rapeseed Oil Using Response Surface Methodology (RSM)-Based Desirability Analysis", Arab J Sci Engg Vol. 39, No. 3, pp. 2277-2287, 2014.
6. Bakrutheen, Willjuice Iruthayarajan and Narayani, "Influence of Ultrasonic Waves on Viscosity of Edible Natural Esters Based Liquid Insulation", IEEE Trans. on Dielec. and Elect. Insul., Vol. 25, No. 5, pp. 1628-1635, 2018.
7. Bakrutheen, Karthick and Madavan, "Investigation of Critical Parameters of Insulating Mineral Oil using Semi Conductive Nano Particles", IEEE International Conference, pp. 294-299, 2013
8. Cheeke, "Fundamentals and Applications of Ultrasonic Waves". CRC Press, NY, USA (2002).
9. Chilaka Ranga, Ashwani Kumar Chandel and Rajeevan Chandel, "Performance Analysis of Alternative Solid Dielectrics of Power Transformers with a Blend of Mineral and Silicon Oils", IETE Tech. Rev., 2017.
10. Fofana, Wasserberg, Borsi and Gockenbach, "Challenge of Mixed Insulating Liquids for Use in High-Voltage Transformers, Part 1: Investigation of Mixed Liquids", IEEE Elect. Insul. Mag., Vol. 18, No. 3, pp. 18-31, 2002.

11. Hossein Hamidi, Erfan Mohammadian, Roozbeh Rafati and Amin Azdarpour, "A Role of Ultrasonic Waves on Oil Viscosity Changes in Porous Media," IEEE Conference, pp. 1-6, 2013.
12. Hamidiab, Mohammadiana, Juninb, Rafatia, Azdarpoura, Junida and Savoryc, "The Effect of Ultrasonic Waves on Oil Viscosity", J Petr. Sci. Tech., Vol. 32, No. 19, pp. 2387-2395, 2014.
13. Rubal Dua, Nidhi Bhandari and Vivek Kumar, "Multi-criteria Optimization for Obtaining Efficiently Blended Transformer Oils", IEEE Trans. on Dielec. Elect. Insul., Vol. 15, No. 3, pp. 879-887, 2008.
14. Raymon, Samuel Pakianathan, Rajamani and Karthik, "Enhancing the Critical Characteristics of Natural Esters with Antioxidants for Power Transformer Applications", IEEE Trans. on Dielec. Elect. Insul., Vol. 20, No. 3, pp. 899-912, 2013.
15. Sharin Ab Ghani, Nor Asiah Muhamad, Zulkarnain Ahmad Noorden, Hidayat Zainuddin and Asimi Ana Ahmad, "Multi-Response Optimization of the Properties of Natural Ester Oil with Mixed Antioxidants using Taguchi-based Methodology", IEEE Trans. on Dielec. Elect. Insul., Vol. 24, No. 3, pp. 1674-1684, 2017.
16. Siti Mariam Yusof, Nuriziani Hussin and Muzamir Isa, "Viscosity Reduction of Palm Oil via Ultrasonic Radiation", J. App. Mech. Mat., Vol. 785, No. 19, pp. 315-319, 2015.
17. Shol, "Industrial applications of ultrasound. In: Ultrasound: Its Chemical, Physical, and Biological Effects", VCH Publishers, Inc., NY, USA, 1988, pp. 97–122.
18. Wilhelm, Stocco, Tulio, Uhren and Batisata, "Edible Natural Esters as Potential Insulating Fluid", IEEE Trans. on Dielec. Elect. Insul., Vol. 20, No.4, pp. 1395-1401, 2013.

AUTHORS PROFILE

C. Rethish Kumar presently studying final year M.E. High Voltage Engineering at National Engineering College, K.R. Nagar, Kovilpatti. His area of interest is liquid dielectric.

Dr. M. Willjuice Iruthayarajan was born in Tuticorin, Tamilnadu, in 1975. He obtained his Bachelor Degree (B.E) in Electrical and Electronics Engineering degree from Government College of Engineering, Tirunelveli. He obtained his Master Degree (M.E) in Control & Instrumentation from Anna University, Chennai and his doctoral degree (Ph. D) in control system from Anna University, Chennai. He works presently as professor and head in the Department of Electrical Engineering, National Engineering College, Kovilpatti, Tamilnadu, India. He has published more than 50 international journals and conference publications. His research area includes control system, instrumentation, evolutionary computation and Liquid Dielectrics.

M. Bakrutheen was born in Madurai, Tamilnadu, in 1989. He obtained his Bachelor Degree (B.E) in Electrical and Electronics Engineering degree and Master Degree (M.E) in High Voltage Engineering from National Engineering College, Kovilpatti, Tamilnadu, India in the year 2010 and 2013 respectively. He works presently as an Assistant Professor in the Department of Electrical Engineering, National Engineering College, Kovilpatti, Tamilnadu, India. He has published more than 15 international journals and conference publications His main research interest includes high voltage & insulation engineering, liquid dielectrics, failure and reliability analysis.