International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Finding the Lubrication oil properties of an Internal Combustion Engine using a capacitive sensor

Elavarasan. G, Thiagarajan. L, Kannan. M, Karthikeyan. D

Abstract: ***The main agenda of this paper is to find the IC engine lubricant properties using a capacitive sensor since in the recent times, investigation on lubricant oil properties that affects the oil life time, has become an area of paramount importance, for many scholars. Liters of lubricating oil present in the engines could be prevented from getting discarded before it attains its useful life, by predicting its life time through its degradation properties. Hence, the different sets of oil samples was tested using a capacitive sensor, to determine the extent to which, these oil degradation properties influence the respective oil life time of the testing samples. It was observed that the variations in the dielectric constant values of the lubricating oil with respect to different pollutants present, was reflected as a varying output voltage from the capacitive sensor. These variations in the output voltage of the capacitive sensor were then recorded and was compared with the results, of similar properties of oil tested, attained using ASTM (American Society of Testing and Materials)methods. These observations made from the comparisons of the test results attained from both the capacitive sensor and the ASTM test methods in the laboratory was eventually co related with the lubricant oil properties such as Total Acid Number (TAN), Total Base Number (TBN), and kinematic viscosity to determine the lifetime of the oil sample.***

Index Terms**: Lubrication oil, oil properties, capacitive sensor, lubricant life time.**

I. INTRODUCTION

In our earlier work, we have clearly discussed about the crude oil production, consumption and the reserves to production ratio of the various countries and various reasons for reducing our dependence upon crude oil based Internal Combustion Engines[1]. In this work the importance to monitor the lubrication oil properties were discussed. Lubrication oil properties are very important to determine the efficiency of an internal combustion(IC) engine. Friction is also an important factor that influences the performance of an IC engine as it primarily inhibits the movement between IC engine components and also reduces the engine's mechanical efficiency. At the same time, friction also plays a vital role in increasing the component wear. The maintenance of mechanical efficiency and the prevention of failure of components in an engine can be treated by a thin oil film which will act as a lubricant as well as a heat transferring material. Added advantages like cost, environmental, and logistical perspectives monitors the lubricant properties will be improved by monitoring the lubricant. One third of world energy resources were utilized to reduce the friction of an IC engine [2]. It has been found that around 2.5 billion gallons of oil were consumed annually by the United States for engine lubrication [3]. Also around 18.6% of the United States energy worth 14.3 billion US dollar can be saved annually by proper lubricant monitoring. The interval for changing the oil were done mostly on the basis of the vehicle mileage instead of oil condition that increases the cost spend as well as the usage of the lubricant oil [4]. The condition of the lubrication oil can be used to predict the various operating parameters of the vehicle [5]. Properties of lubrication of moving parts are a critical factor in IC engine's performance and longevity. Ideal lubricant change interval is a prerequisite for maximum efficiency and useful life. In fact, premature oil change intervals will result in engine wear, cause damages to the engine, increase the vehicle maintenance cost and wastage of natural resources. Thus, this experiment helps in co-relating the various physical and electrical properties of the lubricant oil with the longevity of the oil. The objective of this research is to find the quality of the lubrication oil by measuring its physical properties using a capacitive sensor. The sensor measures the oil density, temperature, dielectric constant and dynamic viscosity. The values were examined by comparing it to obtained results from ASTM methods or compatible bench-top testing. Also to Establish connections between changes in lubricant physical properties and pollution levels.

Table 1: Possible Fuel Pollution Limits By Volume [6]

Pollutant	% Limit 1	% Limit 2	% Limit 3
Fuel	0.5-1.5	Minor 1.5-4.5, Significant 5-7.5, Excessive >7.5	2.5 to 5 max

Manuscript published on 30 June 2019.
***** Correspondence Author (s)
Elavarasan G*, Mechanical Engineering, Annamalai University , Chidambaram, India.
Thiagarajan.L, Automobile Engineering, NCR Campus, SRM IST, Ghaziabad, India.
Kannan.M , Automobile Engineering, NCR Campus, SRM IST, Ghaziabad India.
Karthikeyan.D, Mechanical Engineering, Annamalai University, Chidambaram, India.

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Tables 1 and 2 represent the possible polluting limits for hydrocarbon fuel and solid soot pollution, respectively. However, the reasonable polluting levels to test and connect to the changes in the properties of the lubricant can be taken from this value but not as a generic value. Oil samples were manually taken and polluted with different quantity of fuel so that these connections with respect to fuel pollution level and the properties of lubricant can be created. Any modification in the properties of the lubricant from a regularized baseline was related to the quantity of fuel pollution present in the oil sample. Total Base Number, solid soot, oxidation and glycol measurements were experimented on oil samples taken from the engine to examine specific, potential reasons for the change in the properties of the lubricant.

Table 2: Possible Soot Pollution Limits By Weight [6]

Pollutant	Polluting Limit 1	Polluting Limit 2
Soot	0.2-0.9	Minor 1-1.9 Significant 2-4.5 Excessive >5

II. ENGINE OIL FORMULATION AND OIL DEGRADATION PROCESS

Engine lubricants contain a base stock and additives. The performance of the lubricants can be affected by the base stock in several ways like thermal and oxidation stability of the oil, dynamic viscosity, volatility, and its ability to diffuse additives and pollutants. According to The American Petroleum Institute (API) lubricant base stocks were divided into five groups. In that the Group from I to III were classified by the viscosity index of the oil, saturate and amount of sulfur content of the oil[7]. The polyalphaolefins (i.e. synthetic oils) was classified under Group IV. Esters and other remaining base stock that were not classified in the other groups will be placed under Group V [7]. Mainly the base stock group will be the one of the following either it may be a mineral oil or it is a synthetic oil. Processes like distillation and refinement of crude oil are used to manufacture mineral oils, which initially consist of hydrocarbons along with the presence of O2, N2, or sulfur compounds. The source of the crude oil will determine its molecular structure and this will influence the properties of the lubricant [8]. Synthetic man made base stocks like polyalphaolefins will have a controlled molecular structure. Compound with desired properties can be made by synthetic base stocks, whereas a need for undesired properties can only be fulfilled by mineral oil type base stocks which are usually a mixture of compounds and thus, effecting the required changes. Both the type of base stocks were formulated with the help of additives. The reason for formulating the additives with the lubricant are to increase the performance and some were actually act as an agent of antioxidants, anticorrosive and to improve the viscosity index.[9]. The hydrocarbon will mix with the lubricant in order to remove that the engine oil will react with the oxygen to form a radical and this radical reacts with oxygen to form another radical and this will help to break the bond between the hydrogen and carbon. As this process is irreversible, this will continue until all the hydrocarbon present in the fuel breaks[10]. The reaction of the acid with the lubricant will increase the weight of the molecule thus increasing the viscosity, so the oxidation of the lubricant oil will help to maintain the viscosity [11].

A. Lubrication Mechanisms

Because of the movement of the engine component the hydrodynamic type of lubrication occurs and the viscosity of the oil will affect this lubrication mechanism [12]. Some parts of the engine like piston and cylinder interface will not be properly lubricated because of the change in the direction of the piston which are the reasons for boundary friction, Anti observant additive can be used to increase the performance[13]. Various operating conditions, drive cycle and environmental condition will also affect the lubrication of the engine. During the cold weather conditions water molecules may form inside the engine from atmosphere to the crankcase through the blow by gases between the piston and walls and this will restrict the oil motion and affects the lubrication mechanism [14].

B. Lubricant Property Trends

Several techniques have been developed for on board condition monitoring of the lubricant oil and various case studies have been performed to study about the properties of the lubricants. If the sensors are improved, it can very well eliminate the process of taking the samples to the laboratory for testing and a lot of time will be saved. In [15], the authors recorded the results obtained by using the sensors, which was examined in a laboratory set up of 6500 cc, V-8, naturally aspirated CI engine. The engine was allowed to run for about 8 hours a day and cooled to 70°C in order to record the sensor response. Oil samples from the engine were taken in every 15 hours for analysis and the obtained results were compared with the output from the sensors. The engine was allowed to run for the maximum soot emission concentration and this was recorded in a manual smoke meter and using the sensor. The change in the dielectric constant and the viscosity were measured with the sensor as well as the instrument while increasing the soot concentration. By increasing the temperature upto 150°C the oxidation capacity of the oil is also measured by using the sensor[15]. Some studies are conducted on sensors about the measurement of the electrical properties of lubrication oil. For instance, a lubrication oil sensor developed at Delphi Automotive Systems is used to measure the conductivity of the engine lubricant. Conductivity of the lubricant will vary according to the acidic and the soot concentration of the oil[16].

III. EXPERIMENTAL APPROACH

The experimental setup has a beaker of oil sample of fixed volume (200mL), placed on top of the electrical heater. The capacitance sensor was suspended into the oil, by a burette stand. The oil was then, stirred continuously throughout the experiment by dropping a magnetic stirrer into the beaker. The sensor output was connected through the RS232 to the computer, where the output voltage was displayed in the hyper terminal. Heater was turned on and the temperature was raised to the desired value. Since the effective temperature of the sensor was identified by the above experiment (works the best at 55°C), we decided to heat all the used and unused oil samples to this temperature.

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By doing so we found out the output voltage from the sensor as follows: Firstly, the unused oil of the same grade was heated to 55°C and the corresponding sensor output voltage was measured at the hyper terminal in the computer. This voltage was then calibrated to the unused, particular grade of oil, which was used. The same calibrated voltage was taken as reference for the remaining tests. Various oil samples with pollutants such as soot, Fe, Si content were tested with the capacitive sensor. These samples were then, taken in separate beakers individually, in a fixed volume and heated to 55°C. The voltage output from the sensor was recorded down in hyper terminal.

Figure 1: Experimental setup

A. Working principles

Pollutants present in the oil such as solid soot, oxidation products, H2O, glycol content, along with changes in TBN can change the electrical properties of the lubricant. The dielectric property capacitance of the various tested oil sample varying with the change in the proportion of the pollutant has been shown. The sensitivity of this capacitance measurement is found to be very impressive. The values are found to be increase with the additive of polar molecules like esters, ketones etc. It has been given in the paper [17], that the oil degradation is determined by measuring the change in the permittivity or otherwise called as dielectric constant. When the reason of the dielectric constant is examined to measure the oil properties, it is noted that, it generated the ketone, alcohol and aldehyde which are soluble in oxygen and later it was converted into oxygen acids and carboxylic acids.

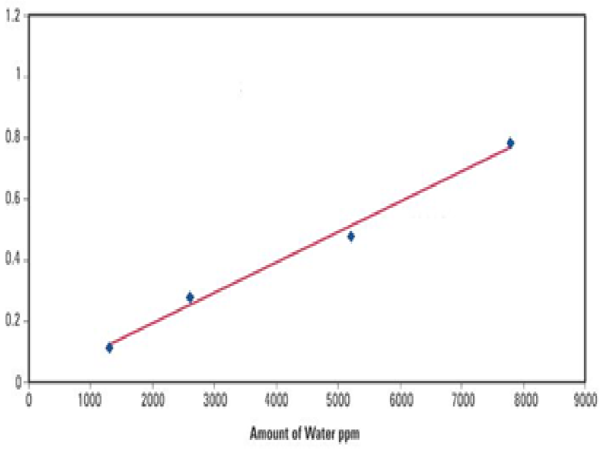

Figure 2: Change of Dielectric constant against the amount of water in ppm GLYCOL

It is also noted that the polarization gets increased with increase in the field strength. S.Raaduni (2006)[18]has tried a grid capacitance sensor arrangement to examine the relative change of the oil degradation due to the physical and chemical properties of the oil, general wear and tear elements and pollutants. In addition the system can also be used to differentiate the relative change of the dielectric constant of oil caused by pollutants such as water. Due to pollution of coolant in engine oil, glycol concentration in the lubrication oil increases. As there is an increase in the glycol concentration, the viscosity of the engine oil also increases. It is also inferred that there is also an increase in dielectric constant and density due to variation in viscosity.

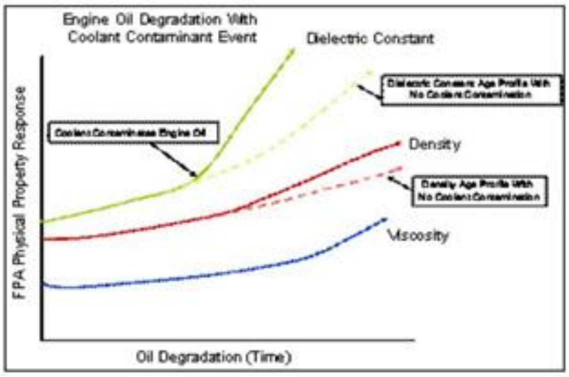

Figure 3: Change of dielectric constant against increase in glycol concentration

Due to blow by gas into crankcase, the oil in the sump turns acidic as the long chain hydrocarbons are broken down into shorter chains .Due to that, the TBN of the engine oil reduces and TAN increases .In turn, as TAN increases, an increase in oxidation in observed.

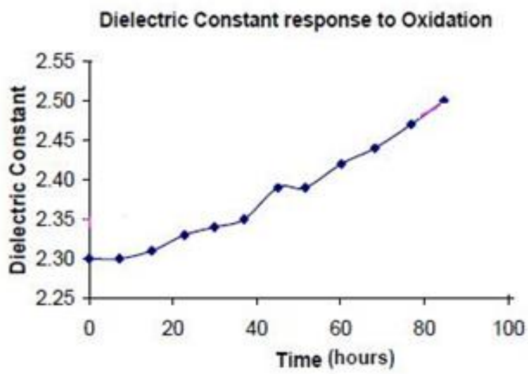

Figure 4: Change of Dielectric constant against increase in Oxidation SOOT

Joel Schmitigal & Steve Moyer(2005) of US Army have tested a dielectric sensor with SAE 15W40 Engine Oil and reported the positive coefficient of Dielectric with soot percentage as shown below [15]. It is to be noted that the increase in dielectric is in spite of the other properties like TBN and TAN when they are well within control. It is verified that dielectric constant is a single measure for all the changes occurring in lubricating oil degradation.

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It is also observed that the individual measurement of properties using different sensors and integration of all of them is cumbersome and not feasible. Hence, smart sensing like using electrical property (dielectric) is a feasible solution.

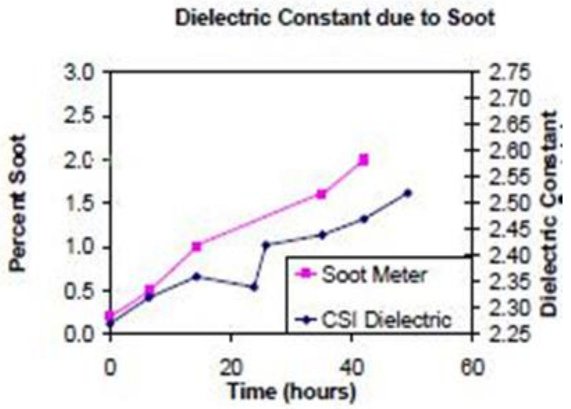

Figure 5: Change of dielectric constant in respect to Soot concentration

B. Precision and accuracy measurements of sensor

The experimental setup consists of a beaker of 200mL volume which was filled with the testing oil sample and a heater unit on which the beaker was placed. Heater was used to heat the oil sample so that it reached the desired temperature. This setup also has a stand to hold onto the capacitance sensor and a thermometer which was immersed into the oil sample as shown on the diagram. Initially new oils from two different oil manufacturers were used as testing samples. 200mL of both the samples were taken into two different beakers. They were heated individually at the rate of °/min till it reached 110°C. The temperature reading from both the capacitance sensor and the thermometer were noted down. This step was repeated for every 5 minutes. The thermometer directly indicates the temperature whereas the capacitance sensor displays the output which includes the oil temperature, pcb temperature and output voltage in the hyper terminal software. Similarly, the oil that was heated to 110°C was allowed to cool down naturally and the relative drop in temperatures was noted for every 5 minutes. In order to have a better cooling effect, the heat transfer by convection from the heater was prevented by placing a tile in between the heater and beaker.

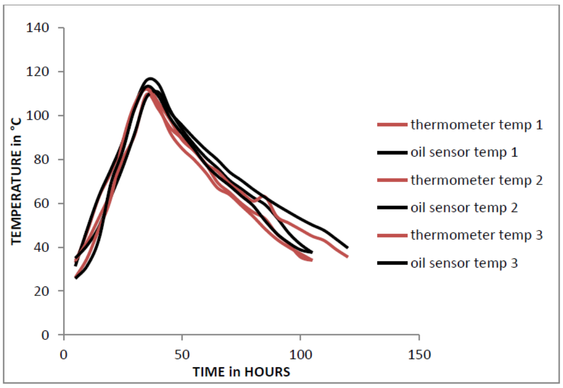

Figure 6: Accuracy measurement of oil condition sensor using temperature assessment in SHELL RIMULA ENGINE OIL (15W40)

A graph was plotted with the readings attained from oil temperatures from both the thermometer and capacitance sensor with time taken on X-axis and temperature taken on Y axis respectively. From the graph attained, we can infer the temperature at which the sensor was found to be most accurate because only at that temperature it responds the best and the fast. It was found that the capacitance sensor was most sensitive at a temperature range between 50-60°C because the sensor generally needs some time to get stabilized to the environment and thus, we took 55°C as the effective temperature at which the sensor's accuracy was the maximum. From the test results in figure 5, it can be concluded that the sensor delivers its maximum accuracy at 55ºC.

IV. RESULTS AND DISCUSSIONS

A. Experiments On Oil Samples:

TABLE 3: SENSOR OUTPUT VOLTAGE OF VARIOUS USED OIL SAMPLES (SET 1)

Parameters	**SAMPLE 1**	**SAMPLE 2**	**SAMPLE 3**	**SAMPLE 4**
HOURS	0	50	100	150
KINEMATIC VISCOSITY (centistoke)	14	13.86	13.97	14.08
TBN mg KOH/g oil	10.51	9.69	9.44	8.99
TAN mg KOH/g oil	3.22	3.72	3.72	3.96
Fe (ppm)	15	59	86	189
Si (ppm)	10	12	14	17
SOOT CONTENT %	0	0.61	0.94	0.99
SENSOR VOLTAGE (volts)	3.667	3.672	3.68	3.684

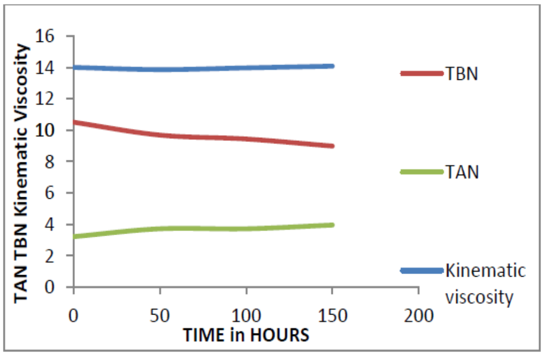

Figure 8: Variation of lubricant oil physical properties with respect to oil life time in Hours (set 1)

From figure 8, it can be concluded that the TBN number decreases slightly for the tested oil sample while the TAN number varied minutely as it deviates upwards. Kinematic viscosity remains constant. This trend observed might be attributed to oxidation in the tested oil sample. From figure 9, it is inferred that the rapid increase in the Fe content and a slight variation in the Si content is due to the ingression of the dust particle in the air that is inducted through the clearance between the piston and the piston rings and forms a direct link with the oil. The soot content however remains almost nullified because of less blow by losses.

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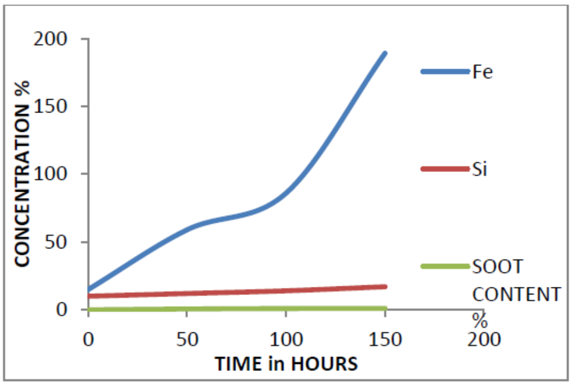

Figure 9: Variation of pollutant concentration in % with respect to oil life time in Hours (set 1)

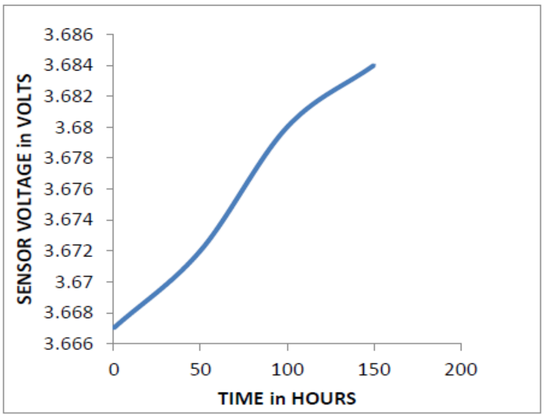

Figure 10: Sensor output voltage for used oil samples (set 1)

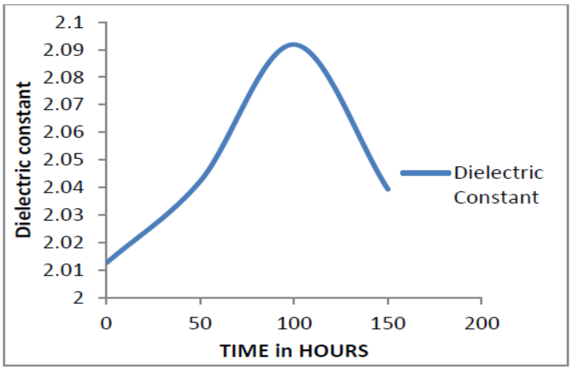

Figure 11: Variation of dielectric constant with respect to oil life time in Hours (set 1)

From figure 10, it is understood that the increase in the Fe and the Si content with slight variations in the TAN number is translated into a sudden increase in the sensor output voltage as shown below. From the test results attained in figure 11, it can be inferred that the dielectric constant of the oil sample increases due to an increase in the presence of Fe and Si content in the tested samples.

TABLE 4: SENSOR OUTPUT VOLTAGE OF VARIOUS USED OIL SAMPLES (SET 2)

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
HOURS	0	50	100	150	200
KINEMATIC VISCOSITY (cSt)	14	14.32	14.34	14.37	14.34
TBN mg KOH/g oil	9.38	8.43	6.35	5.72	5.54
TAN mg KOH/g oil	3.18	3.63	3.87	4.28	4.12
SOOT%(FT-IR)	0	0.64	0.8	1.06	1.34
Sensor Voltage(volts)	3.67	3.674	3.679	3.682	3.683

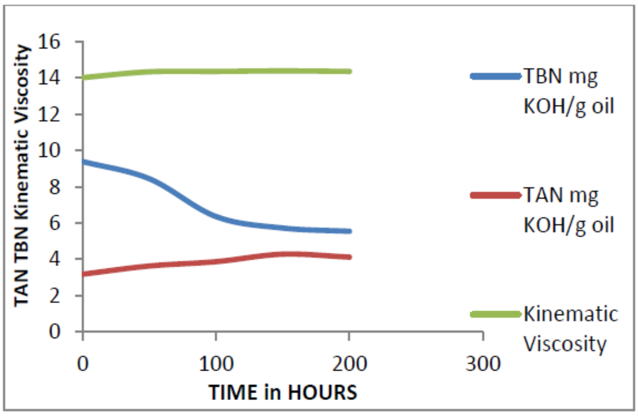

Figure 12: Variation of lubricant oil physical properties with respect oil life time in Hours (set 2)

It is observed from the figure.12 that TBN no. decreases as TAN number increases, while the kinematic viscosity remains nearly constant. This could be explained by the oxidation process which could have happened in the test oil sample that would have in turn, resulted in such a trend.

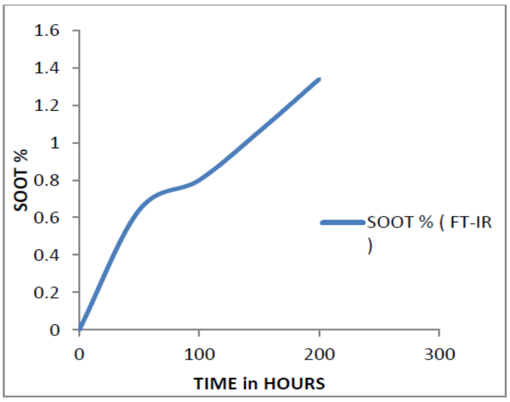

Figure 13: Variation of soot content with respect oil life time in hours

From figure 13, an increase in soot concentration is sighted. This is due to an increase in the blow by losses in engines which in turn, increases the soot concentration present in the oil.`

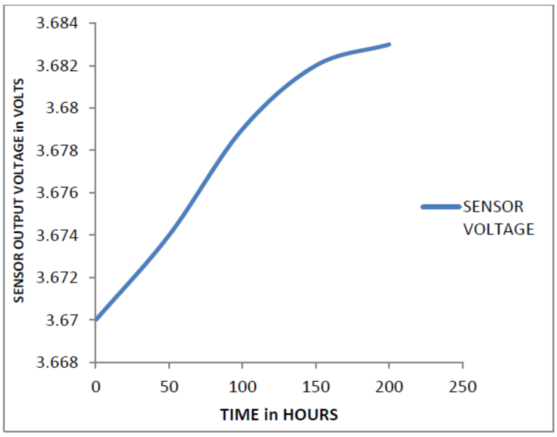

Figure 14: Sensor output voltage for used oil samples (set 2)

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From figure 14, it is noted that there is an increase in the sensor output voltage which is attributed to a phenomenal increase in the soot content and a slight surge in the TAN number against the TBN number.

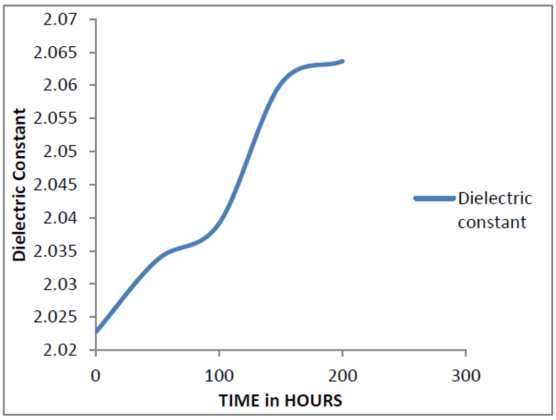

Figure 15: Variation of dielectric constant with respect to oil life time in Hours (set 2)

The test results from figure 15, show an increasing dielectric values with respect to an increasing oil life time in hours because of an increase in soot content present in the samples tested, which concurrently increases both the kinematic viscosity of the oil as well as its dielectric values.

B. Glycol pollution in oil sample

Glycol is mixed with water of about 50/50 in order to make the liquid coolant which will be used to carry away the heat and to raise the boiling point temperature and to reduce the freezing temperature, Because, Glycol is the principle ingredient of antifreeze in nature. Ethylene glycol is mostly used as an additive as it is nontoxic and also it is having high heat transferring capacities in order to use as a coolant [19]. Additives like phosphates, sodium borate, molybdate, potassium sebacate, sodium silicate and sodium nitrate are used in order to prevent the corrosion of the engine and to prevent the foaming and to maintain the pH level. In general from the literature survey we know that, there is an increase in glycol [20](ethylene glycol since it is preferred as the anti-freezing agent in coolant) concentration in the lubricant oil makes the viscosity to increase which leads to thickening of oil, resulting a lower oil debit. If the lubricating oil is Too thick, it is difficult for the oil to circulate and thus resulting in the poor performance of lubricating. Also it leads to acid formation in the oil, which in turn reduces the TBN of the ethylene glycol in the lubricant which causes corrosion.

TABLE 5: SENSOR OUTPUT VOLTAGE FOR VARYING GLYCOL CONCENTRATION

Ethylene Glycol %	0	1	4	5	10
Sensor Voltage (V)	3.667	3.725	3.975	4.396	4.085

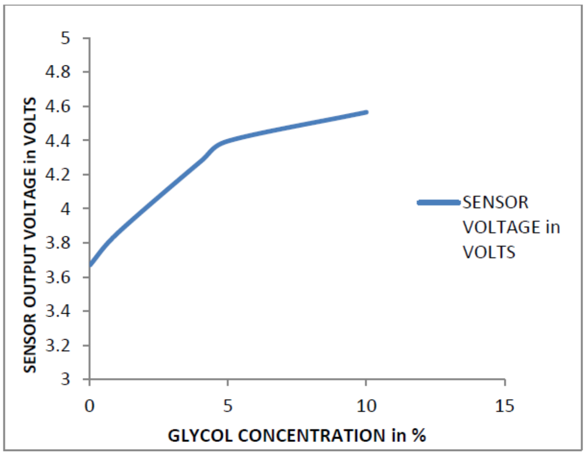

Figure 16: Sensor output voltage for % increase in ethylene glycol concentration

The graph above also proves the study discussed earlier. With an increase in glycol concentration in the lubricant oil, the viscosity also increases leading to oxidation. Therefore, TBN gets reduced in value considerably. This reduction in TBN value denotes that an increase in acidity which in turn causes the current conduction to increase. This simultaneously, increases the sensor output voltage.

V. CONCLUSION

It has been demonstrated that the variations in the output voltage from the capacitive sensor signifies its corresponding variations in the values of the dielectric constant attained for different oil samples, as it has been identified from the tests conducted that, they share a linear relationship. It was also observed that the output voltage obtained from the sensor, varied with the amount of pollutants present in the oil. Hence, these variations were used to co-relate the lubricant oil properties. The analysis showed that the oil life time varies depending on oil degradation with respect to changes in TAN, TBN numbers and kinematic viscosity which was used as a point reference to estimate the longevity of the oil. However, to validate a real time operating condition of lubricating oil in an running engine, the sensor has to be fitted into a real time engine to evaluate its accuracy and performance with respect to the varying operating conditions of the engine.

REFERENCES

1. Elavarasan G, Kannan M, Karthikeyan D “Reasons to Reduce Our Reliance upon Crude Oil Based Internal Combustion Engines” *International Journal of Scientific Research & Engineering Trends* Volume 5, Issue 2, Mar-Apr-2019.
2. Stachowiak, Gwidon W. and Batchelor, 2001 Andrew W. *Engineering Tribology*. Boston: Butterworth-Heinemann
3. *Utah Department of Environmental Quality Division of Solid & Hazardous Waste*, 2009 Utah Department of Environmental Quality. 8 November 2009.
4. Kauffman, Robert E. and Steve C. Moyer, 2002. *“Development and Laboratory Evaluation of On-Board Oil Condition Monitoring Sensors for HMMWV Diesel Engines.”*JOAP.
5. Margrif, F. and Barry Czachura, 2003. “*Lifetime Engine Oil Filtration for Light Military Utility Vehicles.*”RTO-MP-AVT-109.
6. Booser, Richard E. *Handbook of Lubrication*, Inc. 2001. Boca Raton: CRC Press, 2000.
7. Pirro, D.M. and A.A. Wessol. *Lubrication Fundamentals*. New York: Marcel Dekker.

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8. "*Hydrocarbon Base Oil Chemistry.*" Fuels and Lubricants Handbook.175-181.
9. Smalheer, C.V. and R. Kennedy Smith.Lubricant *Additives*. Cleveland: The Lezius-Hiles Co., 1967.
10. Mortier, R.M. and S.T. Orszulik, 1992. *Chemistry and Technology of Lubricants*. New York: Blackie Academic & Professional.
11. Wurzbach, Richard N. "*Oxidation Stability and Strategies for Extending Lubricant Life*." Peach Bottom Atomic Power Station.
12. Lansdown, A.R. *Lubrication and Lubricant Selection*, 2004. New York: ASME Press.
13. Heywood, John B, 1988. *Internal Combustion Engine Fundamentals.*
14. Fitch, Jim, May 2007. "*Four Lethal Diesel Engine Oil Contaminants*."Machinery Lubrication Magazine.`
15. Schmitigal, Joel and Steve Moyer, 2005. "*Evaluation of Sensors for On-Board Diesel Oil Condition Monitoring of U.S. Army Ground Equipment*" U.S. Army RDECOMTARDEC.
16. Wang, Simon S, 2002. "*Engine Oil Condition Sensor: Method for Establishing Correlation with Total Acid Number*" 26.122-126. Sensors and Actuators.
17. Used Oil degradation detection sensor development, (ITC 2006) By S Raadnui.
18. Evaluation of Sensors for On-Board Diesel Oil Condition Monitoring of U.S Army Ground Equipment-Joel Schmitigal Steve Moyer-US Army journal 2003.
19. TakafumiShimoaka, TakeshiHasegawa, "*Molecular structural analysis of hydrated ethylene glycol accounting for the antifreeze effect by using infrared attenuated total reflection spectroscopy*", Journal of Molecular Liquids, Volume 223, November 2016, Pages 621-627
20. Jan Seiler, Jonas Hackmann, Franz Lanzerath, André Bardow, *"Refrigeration below zero °C: Adsorption chillers using water with ethylene glycol as antifreezeFroid en dessous de 0 °C : refroidisseurs à adsorption utilisant de l'eau combinée à de l'éthylène glycol comme antigel"* International Journal of Refrigeration Volume 77, May 2017, Pages 39-47

AUTHORS PROFILE

Elavarasan G received his BE(Automobile) from MIT campus, Anna University, Chennai and MTech(Energy) in SITE,Subharti University, Meerut.The author have published around 5 International journals with ISSN number. He is currently pursuing his Phd (Mechanical) in Annamalai University, Chidambaram. His area of interest is emission control techniques in internal combustion Engines.

Thiagarajan.L received his BE(Automobile) from MIT campus, Anna University, Chennai. The author have published around 3 International journals with ISSN number. He is currently working as an Assistant Professor at SRMIST, Ghaziabad. His area of interest is weight reduction in automobile and improving the passive safety of an automobile.

Kannan.M received his BE(Automobile) from MIT campus, Anna University, Chennai and MTech(Energy) in SITE,Subharti University, Meerut. The author have published around 3 International journals with ISSN number. He is currently working as an Assistant Professor at SRMIST, Ghaziabad. His area of interest is Alternative source of energy for the Automobile sector.

Karthikeyan D completed his doctor of philosophy in the department of Mechanical engineering at Annamalai University, Chidambaram, India and currently working as an Associate Professor in the department of Mechanical Engineering, Annamalai University, Chidambaram. The author have published around 4 International journals with ISSN number and 1 journal with scopus indexing. His area of interest is Engine emission control using selective catalytic reduction technique in the exhaust system. Author is working as a Investigator in a NLC sponsored project.

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