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Spectroscopic Methods For Lubricant Quality Control In Engines And Gear Boxes

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ABSTRACT

Lubricants play a vital role in reducing the wear and tear of engine/gear box metal parts. Number of analytical and spectroscopic methods have been used to analyze the quality of the lubricant oil. Moreover some parameters such as Total Acid Number (TAN), viscosity index also have been used to analyze the quality of the oil. Several used wind turbine gear oil samples were analyzed by various spectroscopic methods such as UV-Visible, Fourier-transform infrared (FTIR) and Fluorescence Spectroscopy. Fluorescence method gave promising results among those three spectroscopic methods. In order to study thermal degradation, motor oil samples were subjected to artificial aging in the laboratory conditions by heating them up to different temperatures for different time periods and then subsequently analyzed with fluorescence spectroscopic method. Subsequently two used engine oil samples from a same diesel engine vehicle were analyzed using fluorescence spectroscopic method. Notable variation in fluorescence emission intensities was observed with oil aging. Intensity of the fluorescence emission signal decrease with oil degradation. Therefore fluorescence spectroscopic method can be used to predict the reusability of gear oils as well as to identify the oil degradation. This method can be further extended to develop a novel potential sensor to detect the quality of oil in various types of engines.

KEYWORDS: *Lubricant oil, Oil degradation, Fluorescence spectroscopy, Analytical methods.*

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1. INTRODUCTION

Identification of oil degradation in engines and gear boxes is important and it is similar to the blood test of human which reveal the condition of the body. Especially, condition monitoring of heavy duty machineries such as wind turbines is essential for a better maintenance (Amiyo et al.,2000). Lubricant oil possesses many valuable properties like protecting engines from effects arising from heat, pressure, corrosion, oxidation and contamination. It functions as a fluid layer between moving parts, reducing friction and wear, cleaning the interior of the engine by removing dirt, wear and combustion contaminants, cooling an engine by increasing heat dissipation, further reducing wear and preventing the entry of contaminants (Liu et al. , 2007). Motor oil consists of mainly two components such as base oil and additives. Base oil is either a mineral oil or synthetic oil (Abdulrahim et al. , 2003). Primary additives are viscosity index improvers, friction and wear modifiers, pour point depressants, antioxidants, corrosion, rust inhibitors and antifoam agents (Aziz et al. , 2003). But however against aging oil slowly degrades by either chemically, physically or by photo-chemically. As a result of degradation, physical and chemical properties like colour, viscosity and acidity are subjected to change. Acidity can be changed due to oxidation and additive depletion. Acids corrode metal parts of the engine (Wolak , 2018). Viscosity of the oil changes due to formation of higher or lower molecular weight segments and subsequently it will effect to friction between engine metal parts. Ultimately it causes severe damage to engine and motor parts.

Currently, the common practice is to change the oil by considering the mileage or working hours, but oil degradation not only depends on mileage but also with many other factors such as weather conditions, engine type and quality of maintenance and etc. (Fitch , 2003).

The aim of this research is to analyze different oil samples of such as new oil samples, artificially aged oil samples, oil samples with different mileages and working hours with different analytical methods and identify most suitable method to track the oil quality. Finally the best suitable method will be further optimized to develop a novel sensor to detect oil degradation. Proper oil condition monitoring helps to save the machine life time as well as oil, otherwise if oil is removed before it degrades, it will be a waste and if it’s too late damages can be happen to engine/gear box motor parts.

2. METHODOLOGY

Wind turbine gear oil samples (five samples) of Mobil XMP 320 samples were collected in to cleaned containers, along with their fresh oils and used oil samples. Sample preparation methods were not used in this research as these spectroscopic methods are non-destructive techniques. Undisturbed samples were analyzed by UV-Visible Spectrophotometer (Thermo Scientific GENESYS 10S Series) under a full scan (200 nm to 1100 nm wavelength range) and by Fourier-transform infrared spectroscopy (Thermo Scientific Nicolet S10 FTIR) using ATR method and further by Fluorescence spectrometer (Thermo Scientific Lumina) at 350 nm excitation wavelength.

Subsequently four sets of 10 ml samples of Caltex DS 40 engine oil were heated under four different temperatures against different time periods in laboratory by using a paraffin oil bath. Then it was analyzed with fluorescence spectrometer at 350 nm excitation wavelength. (Sample details are shown in Table1 & Table 2). Afterwards it has been found that fluorescence method shows promising results for all the oil samples. Therefore, fluorescence analysis was carried out for two used engine oils. Used engine oils were collected from same vehicle at 1400 km and at 2600 km mileages. When the fluorescence analysis was carried out there were no any significant differences for the two used oil samples. Therefore, sample pre-treatment was carried out to see any difference. Sample preparation was carried out by dissolving 20.0 µl of the oil sample in 3.0 ml of ethanol. Data was collected under excitation wavelengths of 280 nm, 300 nm, 320 nm, 350 nm and 400 nm.

TABLE 2.Artificially aged and used engine oil samples (Caltex DS 40)

Sample	Working hours
1	0
2	6760
3	16207
4	6525
5	7522

Table 1:Wind turbine gear oil samples (Mobil XMP 320)

Sample	Age of oil
1	Fresh
2	Heated at 50 °C for 1 hour
3	Heated at 50 °C for 5 hours
4	Heated at 75 °C for 2 hours
5	Heated at 75°C for 5 hours
6	Heated at 100°C for 3 hours
7	Heated at150 °C for7 hours
8	1400 km
9	2600 km

3. RESULTS AND DISCUSSION

None of the sample preparation method was used for wind turbine gear oils as it was necessary to select the best convenient one step method for oil quality detection. Hence FTIR, ATR methods were used for analysis.

The results in figure1 clearly show that there is no significant spectral changes among spectra of oil samples under the selected conditions. Therefore FTIR was not used for further analysis.

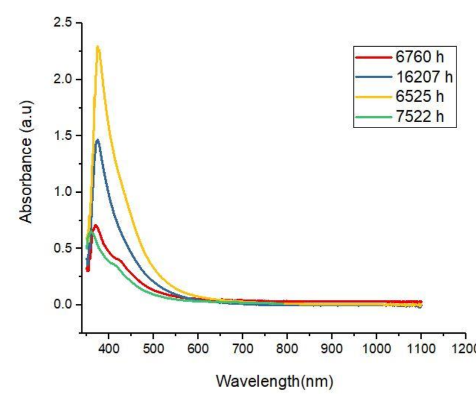

Figure 1: FTIR spectroscopy results of Mobil XMP 320 wind turbine gear oil samples.

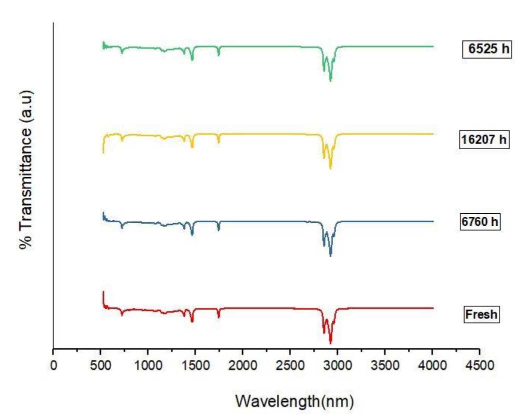

Figure 2: Different UV-Visible spectra obtained for Mobil XMP 320 wind turbine gear oil samples.

Figure 2 shows UV-Visible results of wind turbine gear oil samples. When UV-Vis data are analyze carefully the bands are very close to the cutoff point of the instrument. Therefore UV-Visible method was not used for further analysis.

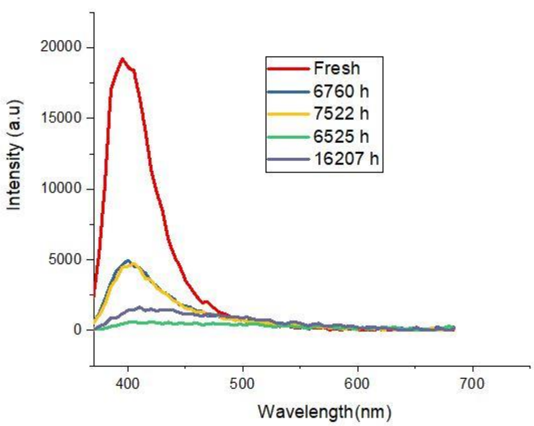

Figure 3: Different Fluorescence spectra obtained for Mobil XMP 320 wind turbine gear oil sample

Figure 3 shows the fluorescence results of wind turbine gear oil samples and as it gives promising results. Therefore, fluorescence was used for further analysis. In addition, fluorescence intensities of degraded samples lie between 0-1000 counts.

Further to that, it emerges a necessity to identity accuracy of the methods which had used. Hence it is decided to carry out a comparative study on this fluorescence results against a complete analysis report issued from a recognized laboratory for the wind turbine samples. Such report usually analyze more than forty parameters to guarantee the outcome results. According to laboratory report, viscosity is in normal range in all wind turbine gear oil samples. In addition as per these reports, it has issued a warning status only for 6525 h and 16207 h samples and it indicates that different parameters were reasoned for the oil degradation in these two degraded samples i.e. the 6525 h working hour sample has degraded due to the increase in molybdenum level. In addition, 16207 h working hour sample has degraded because of its increase in particle count level. 6525 h sample is the least working hours sample, but according to the test report, it indicates that oil was degraded due to several other factors and not suitable for further use. Therefore it shows that the age is not only the parameter that effect the oil degradation.

Apart from gear oils, this research also focuses on auto mobile engine oils. Usually the maximum operating temperature of a wind turbine is between 40 °C - 70 °C. Automobile is between 100 °C -120 °C. But it has been found that when the automobile engine temperature goes beyond 135 °C lubricant oil losses its valuable properties (Marian, 2013), and one such property is viscosity (Santos et al. 2015).

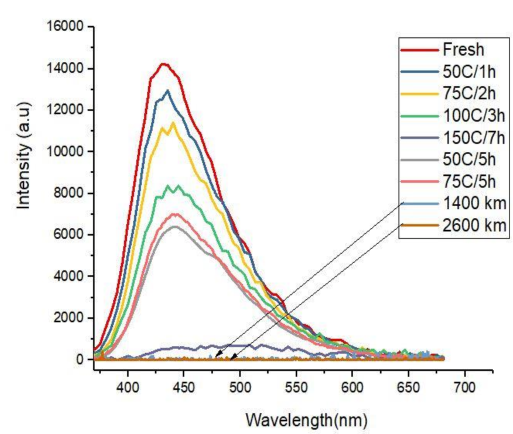

Figure 4: Different Fluorescence spectra obtained for artificially aged and literarily aged Caltex DS 40 engine oil samples.

Fluorescence spectroscopic data of artificially aged "Caltex DS 40" engine oil samples were shown in figure 4. The artificially aged engine oil samples were prepared in order to identify thermal degradation of the oil by fluorescence methods. In figure 4, it can be clearly seen a sudden fluorescence intensity drop in the oil sample heated to 150 °C as it loses oil properties. When more than 150 °C temperature, the intensity lies in between 0-1000.

The fluorescence intensities of both degraded samples of wind turbine gear oil samples and artificially aged engine oil samples lies in between 0-1000. Therefore fluorescence method is chosen as the best suitable method for analysis of lubricant quality.

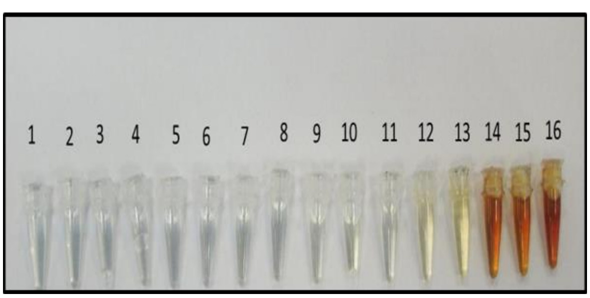

Figure 5: Colour comparison of wind turbine gear oil samples

Figure 5 shows the colour variation of different oil samples. Oil samples are contained in vials. (No: 1- brand new ,No: 2-9 artificially aged oil samples in the lab ,No: 10-13 less than one year used oil from four different turbines, No: 14-16 used old oils samples from three different turbines collected after machine shutdown. Samples were observed with increasing in colour of oil from No: 1 to 16)

In accordance with the graphical analysis of spectra of three spectroscopic methods, FTIR doesn't show any significant variation of the spectra. Fluorescence data shows strong and distinct signals compare to UV-Visible spectroscopic method for both wind turbine gear oil and automobile engine oil. Because of this clear variation of spectra, fluorescence spectroscopy method was chosen as the best method.

Naturally aged engine oil sample series which were collected at 1400 km and 2600 km mileages from same vehicle engine did not show clear fluorescence pattern due to the contamination of fuel carbon residues. Hence 20.0 µl of sample was dissolved in 3.0 ml of ethanol and their fluorescence results were shown in Figure 6.

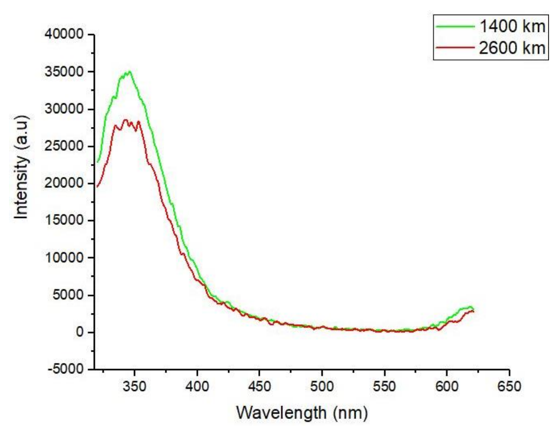

Figure 6: Fluorescence results of used engine oil samples.

According to figure 6, distinct results were given at excitation wavelength of 300 nm. The spectral band position shows a hypochromic shift (blue shift) due to ethanol solvent effect. But the fluorescence intensities shows a distinct variation between these two samples.

In order to clarify that the solvent effect has an effect on analysis, Caltex DS 40 fresh oil and 20.0 µl of Caltex DS 40 dissolved in 3.0 ml of ethanol were analyzed with fluorescence method.

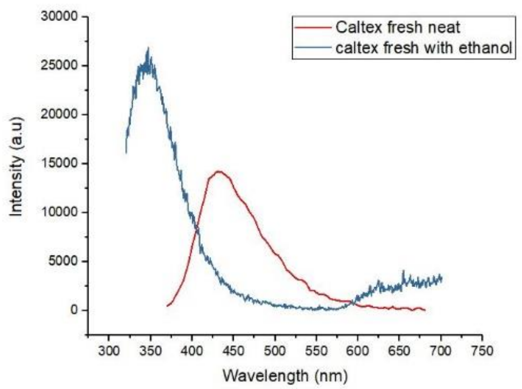

Figure 7: Solvent effect of ethanol in engine oils.

According to results shown in figure 7, it's clear that solvent effect of ethanol causes the blue shift and as well as an increase in fluorescence intensity in the fresh engine oil sample.

Therefore it reveals that fluorescence can be used to identify the oil degradation even in fuel mixed blackened engine oils after a simple sample preparation.

4. CONCLUSION

Several tests have been carried out to discover the feasibility of using fluorescence analysis to estimate the degradation of the oils in wind turbine gearboxes and other engine oils. Used, fresh oils and artificially aged oils were found to produce different patterns for fluorescence data which indicate that this technique can be potentially used for "one step" condition monitoring systems.

According to the results, degradation of gear box oils will be able to easily identify using this nondestructive fluorescence method. It does not require any sample preparation. The variation in intensity of fluorescence emission signal is a good indicator for the oil quality, since emission signal decreases with usage and degradation. There is no correlation between fluorescence intensity with other parameters like viscosity or acidity etc. since degradation does not depend on one or two factors. Hence fluorescence method is an outstanding method among other test methods as it gives similar result even when analyzing more than forty parameters. Therefore the fluorescence bands make it a .versatile analytical technique for the characterization of the composition of complex oil mixtures, such as those in wind turbine gear oils and engine oils.

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