Optical Spectroscopy Study on the Quality of Used Engine Oil

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Abstract— **One of the current global concern today is on the pollution happened to the environment caused by used engine oil. One quart of oil can create a two-acre sized oil slick, and a gallon of oil can pollute a million gallons of fresh water. Some studies say that oil pollution caused 20 years for the environment to recover to its original condition [1]. This paper proposes a study on the quality of engine oil where the aim is to find the exact time to change the engine. This will hopefully lead to reduction in number of time to change the engine oil and extending its life span. The approach use is based on the Non-Destructive Testing (NDT) where percentage of reflectance intensity was measured using MCS600 ZEISS Spectrometer. The data was summed up by a line graph and was verified using statistic approach called *Student t-Test*. The outcome can lead to a conclusion that the more kilometers the engine oil runs (longer distance) the lower the reflectance intensity.**

Keywords—Engine oil, Non-destructive test, Reflectance

I. INTRODUCTION

Engine oil operates as lubricant for various internal moving parts in combustion engines. It also helps to clean, reduce corrosion, improves sealing and cools up the engine [2]. While engine oil is so important in maintaining the performance of the engine, however the engine oil has a finite life where it needs to be change in order to maintain engine protection. The finite life time of engine oil is caused by the changes in physical and chemical properties which will degrade during use time. The quality of the engine oil is a measurement of the engine oil's performance to perform the above functions.

Depending on some factors like engine types, engine's running condition and oil formulation, the engine oil can degrade in many ways, which makes it very difficult to predict the real time to change the engine oil since the exact quality of engine oil can't be determine. For this reason, many engine manufactures or dealers usually advices the customers to change their engine oil at a constant time (usually during service) or according to the mileage interval. However, since the decision for the engine oil change is not based on the real condition of the engine oil, there is possibility that the engine oil could be changed before reaching the end of its useful life. This could cause waste in money and also give bad impact on the environment.

Other researchers have evaluated many studies to find a way in determining the exact time to change the engine oil. This is being driven by expensive oil costs and cost to deposit the engine oil, reduction in vehicle's maintenance's cost as well as regulatory environmental concerns. Somehow, there are few limitations that researchers have to undergo such as determining the most accurate and reliable sensor to measure the engine oil condition, expensive cost to create a model through standard laboratory test, driving test and oil analysis result also the impossibility to create an accurate model for all engine operating conditions, oil types and brands, environmental effects and driving style [3].

In [4-6], an algorithm based system was developed to monitor engine operating parameters such as engine revolutions, oil temperature, fuel usage and etc., to come up with a better way in estimating the engine oil condition. These authors studied and focused on the on-board oil quality monitoring system that based on the measurement of oil physical or chemical parameters.

In this paper, an experiment was conducted to prolonged prior studies done in finding the best way to estimate the quality of engine oil. The approach used here was by using one from the light behavior which is the reflectance of light. Non-Destructive Testing (NDT) was applied where a spectrometer analyzer was used as the equipment to do the measurement. The relationship between percentages of reflectance intensity on the color of engine oil from a different mileage was studied. The engine oil

studied is in grade 10W-40 from MOTUL brand where six samples were took with different mileage.

Non-Destructive Testing (NDT) is the examination of an object or material with technology that does not affect its future usefulness without destroying or damaging a material. NDT provide an excellent balance between quality control and cost-effectiveness [7]. In this experiment, NDT using wavelength electromagnetic radiation was used by measuring the intensity of light reflectance. Reflectance can be define as the ratio of the total amount of radiation such as light reflected by a surface to the total amount of radiation incident on the surface [8]. The analysis was done using MCS600 ZEISS Spectrometer as shown in Figure 1 where it had been interfaced with ASPECT PLUS software to analyze the collected data.

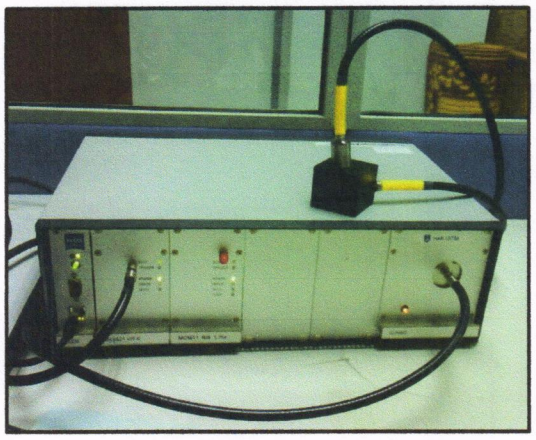

Figure 1: MCS600 ZEISS Spectrometer.

II. METHODOLOGY

Figure 2 illustrates the proposed methodology for this study step by step in a flow chart form. The experiment started by underlining all parameters that may contribute difference in the result. Since the study is due to the mileage (the engine will be run over some distance), other parameters such as brand and engine oil's grade will be fixed.

Next, NDT was selected as the method where measurement on the reflectance intensity was chose to carry out the experiment. A spectrometer analyzer was used as the measurement equipment. Data was collected using syringes at certain kilometers before it was analyzed with spectrometer.

ASPECT PLUS software was used to interpret result obtained from the spectrometer. Microsoft Excel then used to arrange data before it was verified using statistic method called *Student t-Test*, and came out with the final result.

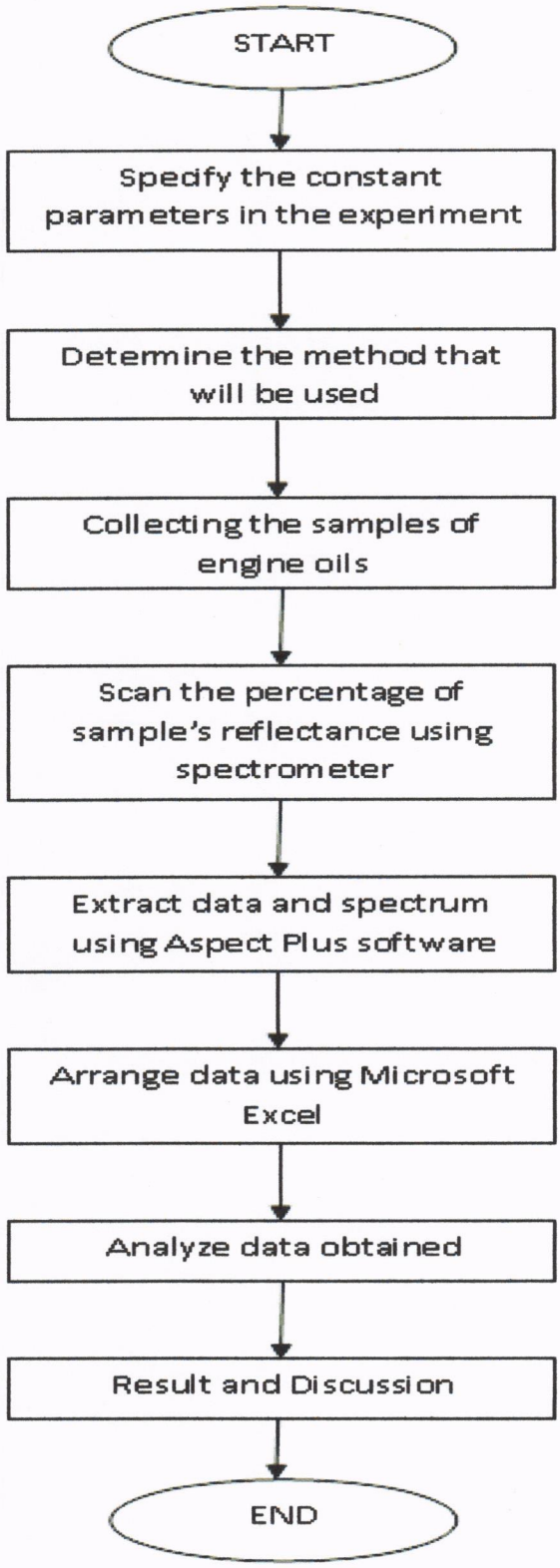

Figure 2: Flowchart of the experiment.

A. Samples & Data Collection

Figure 3 shows the engine oil and other apparatus that was used in the experiment. The engine oil used was type SAE 10W-40 from MOTUL brand. A motorcycle engine was selected as the medium to get

the mileage needed for the engine oil. The motorcycle was running over more than 2000km and a sample of engine oil was collected over certain distance. Syringe was used to take the sample of engine oil from the motorcycle engine and was labeled according to the kilometers to avoid any mismatch like shown in Figure 3(b). Altogether, there are total of six samples that had been collected which are 0km, 60km, 250km, 360km, 460km and 2000km.

The samples then had safely obtained. The next step was to analyze and extract the data from all the samples. Microscopic slides (Figure 3(c)) were used during the testing where three drops of each engine oils samples was drop onto it before another slides will be put on top of it. Fifteen readings were taken for all the samples of engine oil.

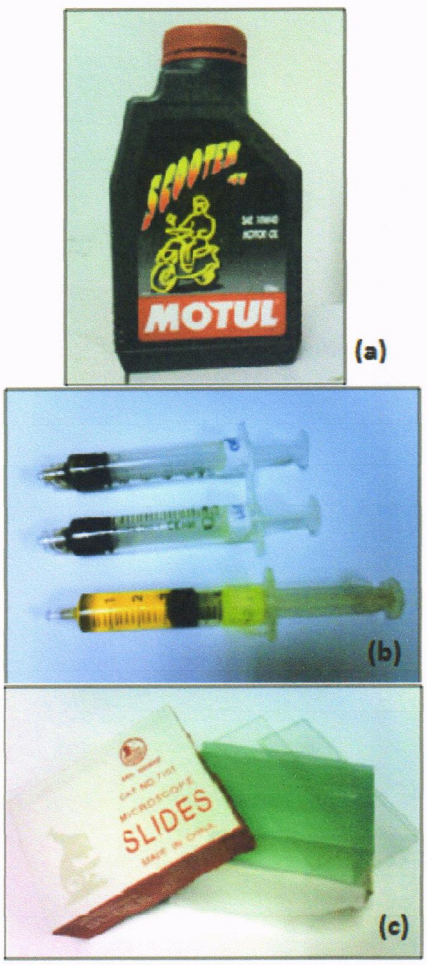

Figure 3: (a) Engine oil from MOTUL brand type 10W-40, (b) The syringes that used to take samples from the engine, (c) Microscopic slides used in data collection.

Then, MCS600 ZEISS Spectrometer was used to measure the reflectance intensity of the samples. To measure how much light hits a surface and how much it reflected, a reflectance measurement of a standard material was taken. A white background was chose as the standard material since it is known that white surface reflect almost all of the light that hits them. White background also used to prevent the effect of light reflectance from the surrounding surfaces.

The result obtained from MCS600 ZEISS Spectrometer was interpreted using Aspect Plus software where a graph of percentage reflectance over wavelength will be formed. The graphs then will be copied into Microsoft Excel to have a data in form of figures.

The data and graph in Microsoft Excel was verified using statistical approach called *Student t-Test. Student t-Test* is one of the tests done to do the hypothesis testing for a small-size sample [9]. In this study, the hypothesis testing was done for the mean of the engine oil, to check whether the hypothesis made should be rejected or not. A graph was plotted too using OriginPro software to observe the pattern of the reflectance percentage over engine oil mileage.

III. RESULT AND DISCUSSION

As mentioned in the Experiment section, the result obtained from spectrometer was arranged in Microsoft Excel. For better view, results are summarized in the form of line chart as shown in Figure 4.

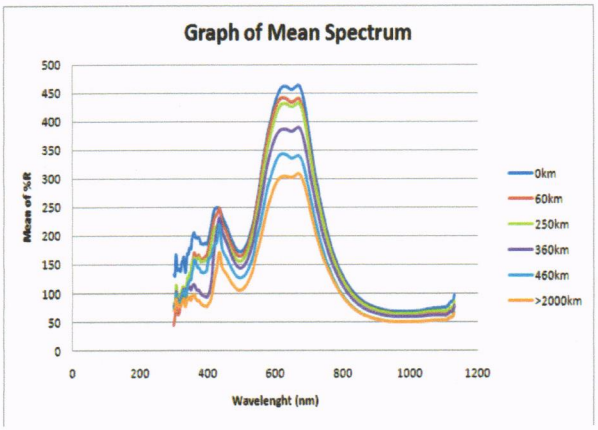

Figure 4: Mean spectrum graph of percentage of reflectance over wavelength for all samples.

Since the results obtained were fluctuated, mean or average of the data was calculated to represent them. As shown in Figure 4, it shows that all the samples have approximately the same pattern, somehow they do differ in term of their maximum or peak value.

Engine oil tends to discoloured usually to opaque and may range in color from dark chocolate brown to light gray. This happens due to the gradual deterioration and contamination. Studies show that oil oxidation products and varnish-like materials called detergent additives that used in oil to keep the engine clean can make the oil turn to dark brown or wine color. The gray discoloration in other case happened

partly because of the road dust and dirt, also due to the decomposition of lead compounds from fuels containing *tetraethyl lead.* Discoloration of engine oil also can exceed to the extent of the engine oil will turn into black or opaque color which may attributed to rich air-fuel mixture and formation of soot and carbon [10].

Since NDT was used in this study, the behavior of light reflectance was applied where dark color absorbs a lot of light and has low light reflectance intensity while light colors reflect most of the light that falls on them and have higher light reflectance intensity [11]. In this case, the light reflectance is referred to the visible light where the wavelength is between 400nm to 780nm.

Based on the study done in [10] and application of theory of light, the result obtained were in the same page with both of them. As shown in Figure 4, 0km sample has the higher mean of reflectance percentage compared to others and 2000km sample has the lowest one. This is due to the discoloration factor that usually occurred in engine oil. The 0km sample which is the new engine oil has the color of light yellow or champagne color, while 2000km sample has the color of black. This can be seen in Figure 5 where three samples were put side by side to compare the color of those three. From all the samples collected the higher mileage of the sample the darker the color of engine oil. For example, 360km sample has darker grayish color compared to 60km sample. This is due to the dirt and road dust that accumulated with the engine oil during the engine running time.

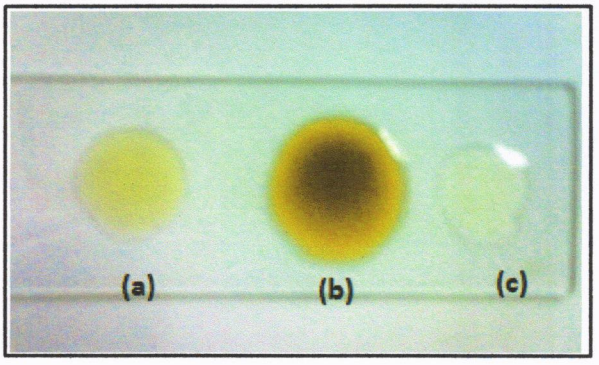

Figure 5: The comparison of color between three samples which are (a) 360km, (b)> 2000km, (c) 60km. It can be seen that the higher the mileage of the engine oil, the darker its color.

Since the longer kilometer of the engine oil will produce darker color, it also has lower reflectance intensity (since dark color reflects light less). Thus, that explain why new oil (0km sample) has higher mean percentage of reflectance compared to the other engine oil samples.

A. Student t-Test

To verify the result obtained, a mathematical approach for small-sample size concerning population mean was done called *Student t-Test.* This test is one from the test that available for hypothesis testing [9]. The maximum peak for almost all the samples were occurred at λ= 667.51nm. Thus, the wavelength was chose as the reference wavelength while calculating using *t-Test.*

Table 1: shows the percentage of reflectance at λ= 667.51nm for each samples.

To do the *t*-Test, the first step to start was to come up with the hypothesis itself.

H_o: $\mu \leq 2000$km
H_a: $\mu > 2000$km

Sample (km)	%R at λ= 667.51nm
0	463.8202
60	440.7236
250	432.847
360	390.5612
460	340.4003
2000	308.9121

The null hypothesis (H_o) stated that the mean for engine oil should be less or equal to 2000km while the alternative hypothesis (H_a) stated that the mean for engine oil should be more than 2000km.

Secondly, the test statistic (*t* statistic) was calculated using (1).

$$t = \frac{\chi - \mu}{\frac{s}{\sqrt{n}}} \quad (1)$$

Where;

$$\chi = sample\ mean = \frac{\sum xi}{n} \quad (2)$$

$$\mu = population\ mean$$

$$s^2 = sample\ variance = \frac{\sum xi^2 - \frac{(\sum xi)^2}{n}}{n-1} \quad (3)$$

$$n = number\ of\ sample$$

From (2), the sample mean was calculated;

$$\chi = \frac{463.8202 + 440.7236 + 432.847 + 390.5612 + 340.4003 + 308.9121}{6}$$

$$= 396.2107$$

From (3), the sample variance was calculated;

$$s^2 = \frac{(960{,}560.0956) - \frac{(2377.2644)^2}{6}}{6 - 1}$$

$$= 3732.48487$$

To find standard deviation, s;

$$s = \sqrt{3732.48487}$$

$$= 61.094$$

From table 1 the mean, μ for 2000km is 308.9121.

Thus, the t-statistic was done using all the values obtained;

$$t = \frac{396.2107 - 308.9121}{\frac{61.094}{\sqrt{6}}}$$

$$= 3.5$$

Thirdly, 5% level of significant ($\alpha = 0.05$) was chose where it means that there are 95% confidents that the null hypothesis (H_o) is true. The right-tailed rejection region was found using the critical values of t from Table 4 of Appendix 1 in [9]. With df = n-1 =5, the null hypothesis (H_o) can be rejected if $t > t_{.05} = 2.015$, as shown in Figure 6.

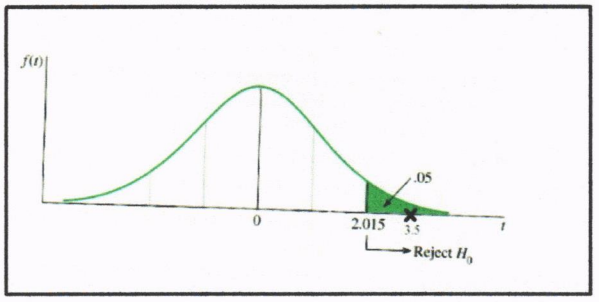

Figure 6: Rejection region for this case was colored in green, where it is actually the region that exceeds more than 2.015.

Thus, since the calculated value of the test statistic is 3.5, falls in the rejection region, null hypothesis (H_o) cannot be accepted. The data do not present sufficient evidence to indicate that the mean for engine oil are less and equal to 2000km. Therefore, the alternative hypothesis (H_a) that says the mean for the engine oil are more than 2000km was proved to be right.

The percentage of reflectance in Table 4 was plotted using OriginPro software to see the pattern of the graph as seen in Figure 7.

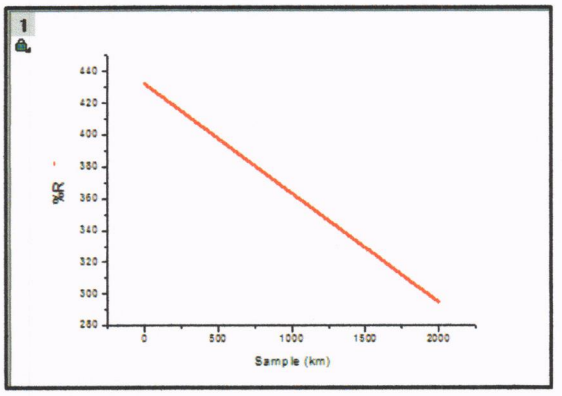

Figure 7: Graph of Percentage of Reflectance vs. Engine Oil Samples

From Figure 7 the relationship between engine oil mileage and percentage of reflectance intensity can be made, where reflectance percentage will decrease with increase in engine oil mileage.

IV. CONCLUSION

Six samples of engine oil; 0km, 60km, 250km, 360km, 460km and 2000km were tested to find their reflectance intensity. The concept of light reflectance was applied on one of the engine oil properties which is discoloration, where it found out that engine oil will change color due to the external factors such as accumulation of road dirt and dust. The difference in percentage reflectance between 0km and 2000km samples was calculated and the change is only for 33.4%. Since the changes are still considerably small, it can be says that the engine oil with the mileage of 2000km does not appear to be wear out yet.

Based on the result obtained one conclusion can be made; reflectance intensity will decrease with increase in mileage of the engine oil. Thus, by using this statement a sensor system applying the concept of light reflectance can be build to check whether the engine oil used in the vehicle is already wear out or not. This can help to predict the right time to change the engine oil, rather than depends on the mileage or last date of services.

V. FUTURE RECOMMENDATION

The study can be improved in the future by collecting more samples of engine oil to verify the result obtained here. It is also recommended to study on the engine oil from other grades which are synthetic and semi-synthetic. In addition, the scope of study can be wide up by including diesel engine.

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