Development of Android Based Application for Monitoring Engine Lubricant Condition in Four Wheeled Vehicle and Driving Behaviour Effects on Engine Lubricant Condition

H S Nugroho¹, M A Dewantoro¹ and D E Atmaja¹

¹ Mechanical Department, Faculty of Engineering, Universitas Indonesia, Depok, Jawa Barat 16424, Indonesia

*Email: henky.suskiito@eng.ui.ac.id, m.akhadewantoro@gmail.com, david.edika@ui.ac.id

Abstract. Engine lubricant is a liquid chemical that is given between two moving objects to reduce the frictional force that occurs. Engine lubricant needs to be replaced periodically to maintain the durability of four-wheeled vehicles. Manufacturers of four-wheeled vehicle manufacturers have given the lubricant replacement period to consumers, but this time period is only a reference. The purpose of this research is to study the calculation method to find the right time to replace the lubricant along with its parameters, study the relationship and characteristics between engine lubricant temperature with coolant temperature, and study the relationship of driving behaviour to decrease engine lubricant conditions. This research was carried out by taking data on engine lubricant temperature and coolant using ANCEL and then analysed it to get the formula for determining engine oil temperature and found the mean absolute error of 0 to 3.60. This research is done by testing the driving behaviour of eco, normal, and sport as far as 300 km for each driving behaviour. In this study, engine speed and coolant temperature data are taken through OBD II and then processed using Raspberry Pi into RPS and engine lubricant temperature then further processed by the backend then the data is sent to Android. On the Android application, the output of the data processing results is displayed as a percentage of engine lubricant condition, engine lubricant remaining distance, and engine lubricant remaining time. The test results show that in sports driving behaviour, the condition of engine lubricant decreased the most at 3.9% followed by normal at 3.18% and the lowest decreased was eco with 2.39%.

1. Introduction
Indonesia experienced the number increase of four-wheeled vehicle users in 2018 that reached 16.44 million drivers, 2.2 times compared to 2008 [1]. Along with these increases, the condition of four-wheeled vehicles in Indonesia developed in terms of production and user adjustments which also occurred all over the world such as three regions, Europe, America, and China and tended to pay more attention to drivers, especially the 'modern' generation with an interest in digital technology [2].

Internet of Things as a term that supports the development of world technology provides opportunities for the automotive sector [3] which results in one in nine survivors of road accidents in developing countries due to the informative ability of four-wheeled vehicles [4]. Around the world, the benefits provided by the implementation of IoT in the automotive sector had an impact on reducing maintenance costs by around 10% - 40% and increasing vehicle life cycles by around 3% - 5% [5]. The change in driver characteristics to 'modern' is in line with the market survey themed "Global Executive
Survey" which said that 58% of four-wheeled vehicle consumers had the appeal of digital devices in accessing vehicle data remotely, checking and diagnosing, and scheduling maintenance activities [6] so that the use of IoT in maintenance activities can provide many benefits.

Vehicle maintenance activities were important to operate in optimal conditions [7] in terms of safety, performance, and comfort. Component that had been identified and considered important to be the subject of this study was engine lubrication systems [8] which needs to be replaced periodically according to vehicle manufacturers recommendation to maintain the durability of engines. The period for changing the lubricant could be influenced by many things, such as engine speed and engine lubricant temperature [9]. The problem with this theory is that only certain vehicles have access to the engine lubricant temperature reading, so it is necessary to find another approach to obtain the engine lubricant temperature value. Therefore, IoT application was designed with Raspberry Pi 3 and OBD II [10] as data collectors, cloud as backend, and Android as data visualization so that users could determine the condition of engine lubricants in real time and calculate the correct timing for replacing engine lubricant.

The research also conducted tests to determine the effect of driving behaviour on the condition of engine lubricant so that four-wheeled vehicle drivers can find out how to drive properly so that the quality of the engine lubricant condition can be maintained.

2. Methodology

2.1. Model Calculation Design

Based on test data performed using a dynamometer, it was found that engine lubricant temperature and engine rotation speed (RPM) can affect engine durability and/or engine lubricant degradation (Figure 1). In addition, based on research conducted on the relationship between lubricant temperature and lubricant life, a parabolic graph was obtained [9].

To increase safety in calculating the lubricant change interval, a constant is made based on the graph. These constants are divided into three parts, namely the constant when the lubricant temperature is below the ideal temperature (k1), at the ideal temperature (k2), and above the ideal temperature (k3).

\[
\frac{1}{(\text{distance to oil change})} = k_1(T_{oil} - T_C)^2 \quad (1)
\]

\[
\frac{1}{(\text{distance to oil change})} = k_2 \quad (2)
\]
\[
\frac{1}{(\text{distance to oil change})} = k_3(T_{oil} - T_E)^2
\]  

Thus, from the distance, oil-aging rate can be calculated with penalty factor, effective revolution, and revolution left.

\[
\text{Penalty Factor} = \frac{\text{distance to oil change at ideal temperature}}{\text{distance to oil change at given temperature}}
\]  

\[
\text{Effective Revolution} = \text{Engine Rev.} \times \text{Penalty Factor}
\]  

\[
\text{Revolution Left} = \text{Engine Rev. Max} - \text{Effective Revolution}
\]

The maximum revolution value was revolutions that can occur throughout the life of the engine lubricant. Nissan Juke engine lubricant must be replaced every 10,000 km [11]. Therefore, the maximum revolution value in this study is the number of engine revolutions that occur to reach 10,000 km with a mixture of various driving behaviours.

In this research, because the programming carried out in this study will process data per second, the value of the engine speed taken from the vehicle (RPM) is converted into the number of engine revolutions per second (RPS) then multiplied by the penalty factor so that it becomes an Effective Revolution. To get the percentage of the latest engine lubricant condition, a comparison of the revolution left value with the maximum revolution value is carried out.

\[
\% \text{ Lubricant Condition} = \frac{\text{Revolution Left}}{\text{Engine Rev. Max}} \times 100\%
\]

Not only in the form of percentage, the result could be shown in days (full driving) and kilometers.

\[
\text{Days Left} = \frac{\text{Revolution Left}}{(\text{Rev. Left per Second}_{t-1} - \text{Rev. Left per Second}_t) \times 86400} \times 86400
\]

\[
\text{KM Left} = \% \text{ Lubrication Condition} \times 10000
\]

In order to obtain lubricant temperature data, it is necessary to convert obtainable data from OBD II such as coolant temperature. It had correlation to lubricant temperature as it followed the coolant temperature value with a bit elasticity and damping [12]. In this research, these correlations were obtained by calculating conversion equation using polynomial with the least MAE. To convert the coolant temperature data, team used ANCEL (non-real-time condition) as lubricant temperature standard and infrared thermometer (BENETECH GM320) to verified real lubricant temperature value.

After conducting a literature study and determining the formula to be used, the modeling was made as a pre-liminary test before testing and taking real data. Modeling is made using the Simulink application (Figure 2). This modeling is done by entering the predetermined formulas along with the required data.
2.2. System and Application Design

Vehicle monitoring applications were built by designing both the hardware and the software. This system contained three main subsystems, the data collecting device, the data processing algorithm, and the data visualization user interface (Figure 3).

The first two subsystems were built using Python language. The data collecting device was designed using OBD II and Raspberry Pi 3 that connected directly from the vehicle with an embedded program to collect parameter values, empirically calculate the component condition and send it to the cloud [13]. The data processing algorithm was embedded in the cloud using the Django framework and PostgreSQL as the database storage (Figure 4). In this framework, the data were being visualized using Android applications that already common in people nowadays.
2.3. Experiment Design
In this research experiment, the test drive was been done using three driving behaviour to look for difference of lubricant condition for each behaviour. The driving behaviours were divided into three stage that determined by accelerator position and coasting time within 1 minute which being calculated from MSA calculation. The results were indices representative driver could maintain the behaviour separately with 14.23% R&R percentage and the behaviour can be differentiated into three behaviour, Eco, Normal, and Sport perfectly (Table 1).

Table 1. Driving Behaviour Parameters

| Driving Behaviour | Accelerator Position (%) | Coasting Time (min/km) |
|-------------------|--------------------------|------------------------|
| Eco               | <12 (16)                 | >1.8                   |
| Normal            | 20 (16) – 25 (27)        | 1.3 (1) – 1.6 (1.8)    |
| Sport             | >30 (27)                 | <1                     |

From above parameters, the test was designed within 300 km distances for each behaviour with Nissan Juke 2015 as observed vehicle. After each behaviour, the components were replaced to keep the lubricant’s condition of every driving behaviour.

3. Result and Discussion

3.1. Lubricant and Coolant Temperature Conversion
Three times data collection of coolant and engine lubricant temperature was carried out to determine the differences and characteristics of the temperature of the coolant and engine lubricant (Figure 5).
The verification of the results was being done during off-condition engine and driving. The average difference of the temperature was 0.4°C or 1.3% error during off-condition engine and 1.4°C or 1.4% error during driving. The conversion equation gave nearly predicted lubricant temperature from coolant temperature with MAE around 0°C – 3.6°C.

From the three graphs, in the first experiment, the temperature of the engine lubricant took longer to overtake the coolant temperature, which was 15.5 minutes. Meanwhile, in the second and third experiments, the meeting point of the two temperatures was relatively faster, namely the 11th minute for the second experiment and the 12.5th minute for the third experiment. This happens because in the first experiment, the test was carried out in the morning when the ambient temperature was lower, while the second and third experiments were carried out at noon when the ambient temperature was higher. Another factor that influences this is that in the first experiment, the test was carried out with the condition of the vehicle at rest in place, while in the second experiment, the test was carried out with the condition of the vehicle being driven immediately as soon as the engine was started, and in the third experiment, the test was carried out with a half test condition carried out when the vehicle does not move then half again while the vehicle is being driven. The results of this test support the theory put forward by Phillips and Termo Industries which states that the vehicle engine will heat up faster (optimum working temperature) when driven slowly after starting. However, the three graphs have something in common, namely the meeting point of coolant and engine lubricant temperature occurs in the temperature range 83 °C to 85 °C.

3.2. Constant and Revolution Maximum Calculation
Determination of constant values is done by performing calculations using various data in predefined formulas (Table 2).
Table 2. Lubricant Constant Value

| Constant | Value            |
|----------|------------------|
| K₁       | 1.81536E-07      |
| K₂       | 2.22439E-07      |
| K₃       | 2.66662E-08      |

The vehicle (Nissan Juke 2015) requires a replacement of engine lubricant every 10,000 km [11]. In this study, the maximum revolution value is obtained from data collection of eco, normal, and sport driving behaviour which is carried out as much as 300 km per one driving behaviour. The three data are combined and converted into 10,000 km (Table 3).

Table 3. Engine Revolution Total Each Behaviour

| Driving Behaviour | Engine Revolution Total |
|-------------------|-------------------------|
| Eco (300 km)      | 556761.4                |
| Normal (300 km)   | 704305.6                |
| Sport (300 km)    | 962652.7                |
| Mean              | 741239.9                |

Thus, the maximum revolution obtained was 24707996.67 revolution.

3.3. Application Program

The built system that consisted of three main systems were each simulated to do exchanged data information through either internet or USB in laptop. The simulation was resulting in good real-time condition with each second accurate data (Figure 6).

Figure 6: Android User Interface with Output Data Information

3.4. Engine Lubricant Condition Experiment
In this subsection, the result condition of engine lubricant using empirical calculation and shown result on application were described for each driving behaviour in the end of session for 300 km. For Eco behaviour, the result values were shown on Table 4.

**Table 4. Eco Behaviour Experiment Result**

| Information           | Empirical Calculation | Application Shown Result |
|-----------------------|-----------------------|--------------------------|
| Revolution Reduction  | 590832.44             | 590832.44                |
| % Lubricant Condition | 97.61%                | 98%                      |
| Distance Left (km)    | 9760.87               | 9761                     |
| Time Left (days)      | 13.11                 | 13                       |

For Normal behaviour, the result values were shown on Table 5.

**Table 5. Normal Behaviour Experiment Result**

| Information           | Empirical Calculation | Application Shown Result |
|-----------------------|-----------------------|--------------------------|
| Revolution Reduction  | 786729.79             | 786729.79                |
| % Lubricant Condition | 96.82%                | 97%                      |
| Distance Left (km)    | 9681.59               | 9682                     |
| Time Left (days)      | 10.03                 | 10                       |

For Normal behaviour, the result values were shown on Table 6.

**Table 6. Normal Behaviour Experiment Result**

| Information           | Empirical Calculation | Application Shown Result |
|-----------------------|-----------------------|--------------------------|
| Revolution Reduction  | 962652.70             | 962652.70                |
| % Lubricant Condition | 96.10%                | 96%                      |
| Distance Left (km)    | 9610.39               | 9610                     |
| Time Left (days)      | 6.37                  | 6                        |

From the results of the verification of the results of the application, it was found that the results of data processing and the results of data processing through the application showed the same results, only on the Android interface, the results shown did not use decimals so the results were rounded to the nearest unit. This rounding causes a maximum error of 0.5% which is caused by rounding on the percentage of engine lubricant condition.

Of the three driving behaviour test results, testing with eco-driving behaviour recorded the smallest decrease in engine lubricant condition compared to normal and sport, which was 2.39%. This is because, during testing of eco driving behaviour, the number of engine revolutions required to drive 300 km is not too large. From the test results of eco-driving behaviour, the average engine rotation speed of the vehicle is only 1,203 revolutions per minute (rpm).

In contrast, of the three driving behaviours, tests with sport driving behaviour recorded the largest decrease in engine lubricant condition. From the tests carried out as far as 300 km, there was a decline in the quality of the engine lubricant due to sports driving behaviour by 3.9%. The average engine rotation speed during the sport driving behaviour test is 2589 rpm.

The normal driving behaviour records a decrease in the quality of the engine lubricant in the middle between eco and sport driving behaviour. From the test results of normal driving behaviour, the decline in the quality of engine lubricants was recorded at 3.18%. The average engine rotation speed in the normal driving behaviour test is also between eco and sport, which is 1483 rpm.

From the three test results, it can be stated that a person's driving behaviour while driving a vehicle can affect the condition of the engine lubricant. The deeper the accelerator lever is pressed, the higher the engine rotation speed and the faster the engine lubricant condition decreases. In addition, one of the parameters in driving behaviour is coasting driving. The more coasting frequency during driving, the
more efficient the consumption of engine lubricant will be. This can be proven in the results of this test where testing for eco-driving behaviour has decreased the least amount of lubricant consumption.

The results of this test also prove the correctness of the factors that influence the condition of engine lubricants proposed by Nissan. From the factors put forward by Nissan, there are two factors that can be proven in this test, namely driving briefly with cold temperatures and using vehicles with continuous idling. This is because the engine lubricant operates outside the optimum temperature and the short driving time makes the engine lubricant temperature does not reach the optimum temperature. In addition, continuous idling causes the condition of the engine lubricant to be continuously consumed without the movement of the vehicle.

4. Conclusion
The conclusion of the study was as follows:

• The engine lubricant temperature always follows the coolant temperature without a definite difference and the time it takes for the engine lubrication and coolant temperatures to meet (temperature meeting point) was influenced by the outside temperature of the vehicle and the test method;

• The meeting point for coolant and engine lubricant temperature was always in the range 83 °C - 85 °C;

• Parameters to determine the condition of the engine lubricant were engine lubricant temperature and engine rotation speed;

• Accelerator position and coasting frequency, which were driving behaviour parameters, affected engine lubrication deterioration;

• The designed application could calculate engine lubricant condition in percentage, days, and distance output.

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