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A Study on Sensor Design for Measurement of Automobile Engine Oil Degradation and Level

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Abstract. In this paper, the sensor design was measurement of automobile engine oil degradation and level. The sensor was designed for the measurement of the change in capacitance according to the change of permittivity between the electrodes Degradation and level sensor insulated from each other, regardless of the measure it was designed to be. Temperature conditions of the experiments were fixed between 79 and 81℃ for consistent measured value. As a result of the experiments, after consumption of blend additive to oil degradation, so variation of capacitance is 18.41 pF according to oil degradation. Sensitivity is 0.493 pF/mm according to change of oil level, and Error is less than ± 0.227 pF/mm.

Keywords: automobile engine oil; capacitive sensor; oil degradation; level sensor

1. Introduction

Automobile market has been developed for a convenient lifestyle of the modern society. Optimum timing of engine oil change is to prevent accidents of the engine, to save resource and for the protection of the environment. Most of the engine oils are based on mineral oil made from petroleum through refining. It is formed with a very complicated molecular structure because of the addition of various additives in order to improve this property. Accordingly, various studies have been carried out to judge the oil state, and recently the studies are focused on a method which makes use of permittivity, which is the electric property of oils [1]. Engine oil forms a film on each moving section of the engine and cools off the friction on the surface of pistons. It also prevents corrosion and oxidation caused by condensation and combustion to ensure that the durability of the engine. However, engine oil degradation and decreasing oil level can lead to an accident with the engine damage. Since 1980, when research on the life of oil began, a variety of methods for measuring oil degradation have been introduced [2-5]. However, sensors can be difficult to develop according to the engine temperature, automobile leaning, and installation location.

This paper is for sensor which consists of an array of plates for degradation and level measurement of the automotive engine oil. Sensor was designed for a limited space in the drain hole of the oil pan. Sensors due to surface tension by design; changes to remove oil trap phenomenon, and increased sensitivity to oil degradation and to allow independent measurement of the level of the system was designed.

2. Principle of the engine oil degradation and level measurement

2.1. The principle of measuring degradation

As the mileage increases, the degradation, the initial property changes and it makes progress inside the engine due to the formidably high temperature and pressure. According to lubrication and engine cleaner by degradation, engine oil has decreased functions. Oxidation will occur according to the increase in corrosion

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and sludge. This phenomenon decreases the engine life. Key parameters of change engine oil degradation is TAN, TBN, viscosity, color, content of water and cooling water. In general, degradation of the engine oil according to increasing TAN, TBN will decrease [5]. In this paper, oil degradation is determined by measuring the change in permittivity. When the cause of permittivity change is analyzed to measure the oil degradation, it is identified that the oxygen compounds with oil solubility, such as ketene, aldehyde and alcohol are generated first, and then they change into organic substances like carboxylic acid and oxygen acid [6]. Such products are polar molecules with acidity. As for the relationship between the field strength E applied to the dielectric substance and the polarization P, the polarization gets bigger when the field strength increases as shown in the equation (1).

$$P = \varepsilon_0 \chi_e E \tag{1}$$

And the relationship, which is indicated in the equation (2), is established between the relative permittivity ε_r and the electric susceptibility Xe, which represents the degree of polarization caused by the electric field that is applied to a certain substance.

$$\varepsilon_r = 1 + \chi_e \tag{2}$$

The deteriorated oil with polar molecules appear to have a bigger electric susceptibility than the non-deteriorated engine oil with non-polarization, and it is greatly affected by the metallic particles and metallic ions that increase due to corrosion and abrasion. Accordingly, it can be identified that the more the engine oil is deteriorated, the more the permittivity of the engine oil is increased. The change in capacitance value is based on the change in the permittivity caused by the degradation of the engine oil (3).

$$C = \varepsilon_0 \varepsilon_r \frac{d}{A} \tag{3}$$

2.2. The principle of measuring level

Oil level decreases with the oil pan leak, damage of gasket and oil drain valve, evaporation according to oil degradation. In general, the oil pressure sensor mounted on the dash by the pressure drop of the oil level warning lamp oil intake is lower than the installed oil pan, or oil pressure is very low operation condition, if more than about 5atm(pressure less than 0.5). When the lights turned on, the driver stopped to check if the engine can lead to engine damage. The user can check the oil level with the use of a dip stick in the automobile bonnet. However, the inspector used cannot be trusted by taking a subjective view, real-time monitoring is impossible. Engine oil level measurement is used to change of permittivity of the dielectric ε_r [6]. In general, permittivity of both air and oil is either 1.00059 or 2.2. Capacitance's measurement with decrease when exposed to air and the sensor is in the oil level.

2.3. Sensor design

The engine oil degradation and the level sensor for the measurement was produced. The electrode was produced for the defense of the FR-4 warp phenomenon at high temperature. Two sides of the Au electrode were produced by electroless plating by using a thickness of 0.035 mm (Fig 1). The structure of the automobile operates in such a way as to prevent damage due to the oil temperature, Teflon was used. In general, Teflon is limited the temperature above 350 ℃. The sensor is suitable for production. Also, by having a low permittivity, the insulation between the electrodes was performed. The sensor was designed within the limited space in the drain hole of the oil pan. Temperature sensor was designed for package was to operate at a fixed temperature. Therefore, the permittivity by temperature change was to ensure data reliability.

Fig. 1: Sensor electrode design.

2.3.1. Plate type sensor design

Electrode gap to smooth the flow of oil to 0.6 mm was designed. Considering the limited space of the oil drain valve, the bar structures were produced to the package structure. Capacitance was measured by inserting an electrode between the structures. Lead frame was used to connect the electrode. The electrode wires were connected from the outside of the structure. Oil valve proceeded by threaded and receptacle with plug made by combining circularly. A combination of the structures was used in the EPO-TEK to maintain a temperature of about 100 ℃ and was produced by curing for 10 minutes in the oven.

Figure 2 is a photograph of the sensor experiments. Always measure the degradation of the oil from the oil from which the state is measured. However, the oil and air levels are measured by the difference in the permittivity. This is done by measuring the sensor exposed to the air by the permittivity of the air should be measured capacitance. However, the sensor electrode is made up of a horizontal array and the oil trap phenomenon has occurred. Problem occurs due to this phenomenon over time, when oil is not removed or if there is a small impact of oil trapped due to the surface tension of oil is not removed.

2.3.2. Slope type sensor design

Sensor of slope was produced to remove oil trap phenomenon due to surface tension. Plate from the slope of the structure was removed when the oil trap phenomenon was confirmed through experiments. Figure 3 of the electrodes is the designed sensor structure which is to have a slope of 30°. Increased sensitivity in the structure of the electrode plate spacing was reduced to 0.3 mm from 0.6 mm and was produced.

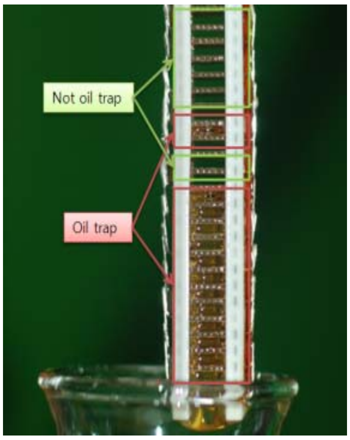

Fig. 2: Oil trap phenomenon.

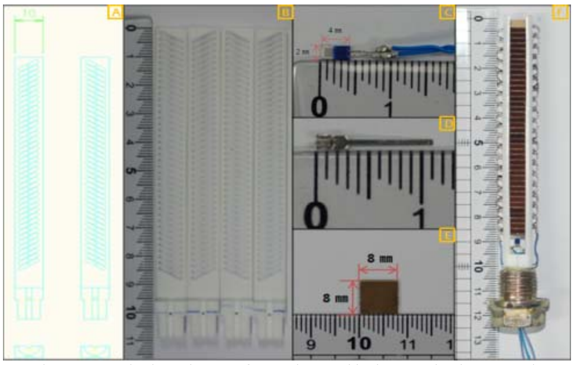

Fig. 3: Fabrication of engine oil degradation and level sensor (A: structural design, B: production structures, C: temperature sensor, D: electrode frame, E: electrode, F: sensor packaging).

3. Experiments and results

3.1. Oil trap phenomenon

Figure 4 is a graph for the confirmation for the removal of oil trap phenomenon. The slope was an experiment using a sensor, the used oil is new oil. By driving the oil temperature was measured to be around 79 ~ 81 ℃. By removing the sensor from oil into air over time, a change in capacitance was observed. Removal from the oil sensor was measured 15 minutes after a rapid decrease in capacitance appeared. The slope sensor does not get the oil trap phenomenon, by heat the oil viscosity is lowered and the oil is removed from the sensor. 15 minutes to 60 minutes after removal of the sensor, change in capacitance is 1.1 pF. Therefore, the oil sensor is exposed to air after 15 minutes of removal.

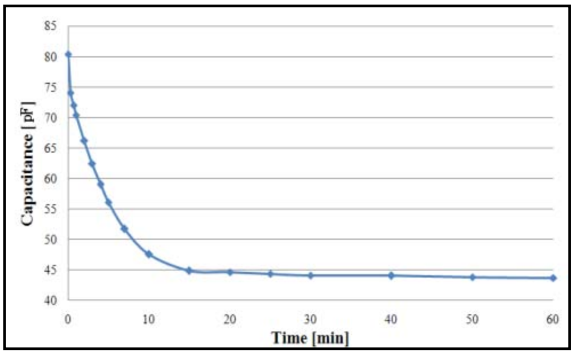

Fig. 4: Experiment oil trap phenomenon

3.2. Experiment conditions

Degradation was measured on using the oil sample of fresh oil until the 10000 km. The oil grade used in this experiment was 5W20 of SAE specification. And the oil was collected from a gasoline automobile for business use and mainly runs in the cities. Degradation and level sensor were insulated from each other; it was designed to be regardless of the measure. By measuring the surface tension of the oil trap phenomenon it was removed from the sensor and then, after 15 minutes it was measured. Using the hot plate the data was measured between 79 and 81 ℃ of oil temperature. In an experiment, stirring at 500 rpm in order to prevent the precipitation of corrosive oil and the oil inside the oil pan to meet the experiment was performed in circulation. For the analysis, change in the capacitance due to input frequency; frequencies of 0.12 kHz, 1 kHz, 10 kHz, and 100 kHz is applied. For validity, the included error in data measurement is more than 500 times and sampling period was set to 5 seconds.

3.3. Experiment result

Fig 5, 6 of the input frequency and mileage according to capacitance and resistance is a graph of change. Capacitance and resistance values are measured at 0.12 kHz input frequency sensitivity which is the largest Sensitivity is decreased accordingly by increasing the input frequency. Mileage according to the capacitance and resistance characteristics of the opposite seems to change. This is due to oil degradation and oxidation is due to the change in oil properties. Capacitance according to the oil and chemical degradation is caused by acid, is increased. Accordingly, the capacitance and TAN (total acid number) is increased [5]. In contrast, resistance to the piston movement and sludge in the engine is due to the increased mechanical changes caused by the alkali resistance of the material and the TBN (total base number) is reduced. Sensitivity is the highest for the input frequency from 0.12 kHz and to analyze this, the value is measured. Four types of the highest in the new oil of the oil sample capacitance 88.4 pF value were measured. Because the injected synthetic base oils and various additives is the initial capacitance. Subsequently, when oil is measured at 2000 km mileage 22.15 pF to 66.25 pF capacitance, make sure to decrease. The initial additive oil is dispersants, perfume agents, antioxidants and the effect is due to the reduced total acid number. Increased mileage oil sample causes a continuous increase in capacitance, resistance is reduced. At 7000 km, the oil sample capacitance represents an increase from 11.35 pF to 77.6 pF. After exhausting the initial additive degradation and oxidation by the TAN value, the capacitance increased. At10000 km, the oil sample represents a continuous increase, 84.66 pF were measured. Since the depleted oil additives were risen more than 20 pF capacitance, it must be replaced. In addition, it gives engine oil degradation to users which will prevent accidents.

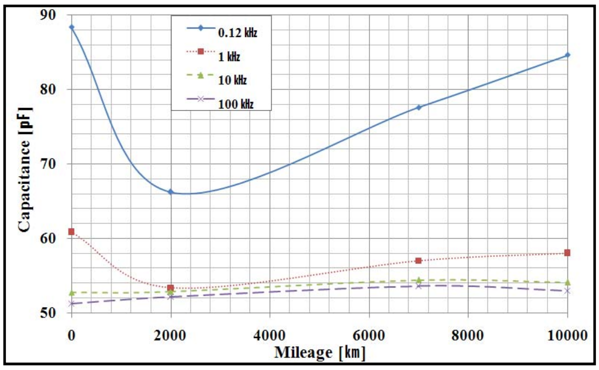

Fig. 5: change in capacitance due to frequency and mileage

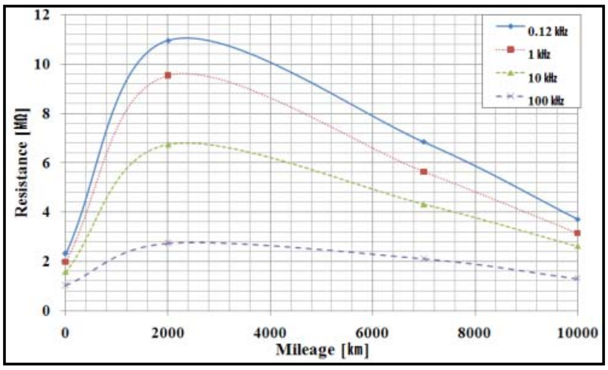

Fig. 6: change in capacitance due to frequency and mileage

Fig. 7 is change of the capacitance to result by oil level and input frequency 0.12 kHz. Sensors have 85 mm electrode length, and oil level is decision according to measurement of capacitance change by 10 mm unit. When in the air of oil sensor and the capacitance are measured by making was ideal graph. As a result of the experiments, be compared to ideal values up to 0.227 pF/mm, at least 0.009 pF/mm have seen the error and average error is 0.088 pF/mm. sensitivity is 0.493 pF/mm according to changes of oil level. The change in capacitive shown at least 2000 km of mileage oil from sensitivity 0.344 pF/mm. The sensor was confirmed that can measure 10 mm oil level through experiment.

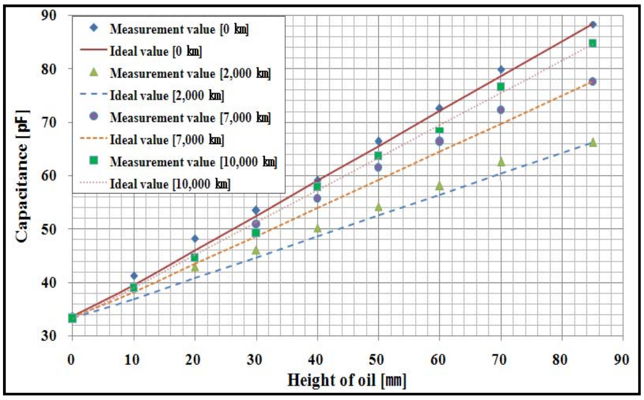

Fig. 7: Change of capacitance due to oil level and mileage

4. Conclusions

In this paper, the sensor design was measurement of automobile engine oil degradation and level. The measured capacitance is increased 18.41 pF due to oil degradation after exhaustion of additives of oil. Saving was of the minimum value of capacitance by exhaustion of additives of oil. Due to the increase of mileage was measured by increasing of the determine oil degradation. Oil level is decision according to measurement of capacitive change by 10 mm unit. Measurement error is less than ± 0.227 pF/mm and the change was of the minimum capacitance 0.344 pF/mm. The sensor was confirmed that can measure 10mm oil level through experiment. However, there still remains the further works to be supplemented, such as the minimizing the influence of output ripple of the processor that is designed to acquire the stable result values, and the test in which the sensor is installed in actual vehicles through miniaturization of the circuit.

5. Acknowledgements

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