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Engine oil measurement using a surface acoustic wave sensor

横波型弾性表面波センサを用いたエンジンオイル測定

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1. Introduction

Engine oils are lubricating oil to move engines smoothly, and a role of engine oils is reduction of the friction and dissipate of the heat mainly. The engine oil deteriorates by soot and iron powder by the metal abrasion and mixture of the water. Deteriorates operation efficiency of the machine. In addition, it leads to aggravation and power down of the mileage, narrowing the life of the system again when we continue using the oil which deteriorated. The deterioration of the oil evaluation is relying on indirect parameter such as the mileage from the last oil exchange, oil temperature and the speed of the engine were mainly investigated[1]. We cannot distinguish a state of the real oil from such an evaluation. Therefore, we decided to examine a deterioration evaluation of the oil using the shear horizontal surface acoustic wave (SH-SAW) sensor in this study. The SH-SAW sensors have been applied for immunoreaction detection[2], liquid evaluation[3], blood clotting monitoring[4] and so on. Merits of the SH-SAW sensor are small size and the real time monitoring. Based on these researches, the SH-SAW sensor has been applied for monitoring oil[5].

In this paper, oil extracted from motorbike was measured with the SH-SAW sensor. The used oil was compared with new one. The results indicate that the SH-SAW sensor can apply for oil monitoring.

2. SH-SAW sensor

The SH-SAW sensor was fabricated on 36ºYX-$LiTaO_3$. The SH-SAW sensor used was dual delay-line with open and short channels. **Fig 1** shows the SH-SAW sensor. The central frequency is 51.5MHz. The finger of IDT is 32 pairs, and the wavelength is 80μm. I put a liquid in the silicon pool on the sensor with a pipette at the time of the experiment. Electrical properties of liquid, such as dielectric constant and conductivity are obtained from the open channel. Mechanical properties, such as viscosity and density are obtained from the short channel[3]. Both electrical and mechanical properties of oil were simultaneously measured by the SH-SAW sensor.

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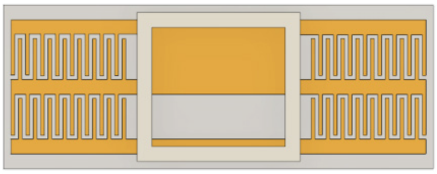

Fig. 1 Schematic of the SH-SAW sensor used.

3. Measurement system

Measurement system is shown in **Fig. 2**. Output signal from a signal generator was fed to the SH-SAW sensor. Output signals from the SH-SAW sensor of phase and amplitude were measured by a vector voltmeter.

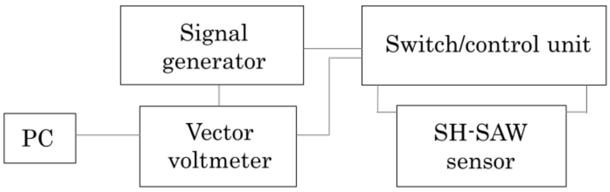

Fig. 2 Measurement setup.

4. Results and discussions

We measured the used and new engine oils. The olive oil was used as reference. Because the viscosity of the olive oil is almost same with the engine oil. Differences of phase and amplitude between the samples and reference was measured. Then those values were converted to velocity and attenuation changes. In addition, we apply the velocity and attenuation changes to permittivity - conductivity chart[3], and to evaluate a characteristic difference of olive oil and the engine oil. Here, the permittivity - conductivity chart referred to relations of dielectric constant and conductivity from the theoretical of velocity change and attenuation change of eqs. (1) and (2) on the chart.

$$\frac{\Delta V}{V} = -\frac{K_S^2}{2}\frac{(\sigma'/\omega)^2 + \varepsilon_0(\varepsilon_r' - \varepsilon_r)(\varepsilon_r'\varepsilon_0 + \varepsilon_p^\tau)}{(\sigma'/\omega)^2 + (\varepsilon_r'\varepsilon_0 + \varepsilon_p^\tau)^2} \quad (1)$$

$$\frac{\Delta\alpha}{k} = \frac{K_S^2}{2}\frac{(\sigma'/\omega)(\varepsilon_r'\varepsilon_0 + \varepsilon_p^\tau)}{(\sigma'/\omega)^2 + (\varepsilon_r'\varepsilon_0 + \varepsilon_p^\tau)^2} \quad (2)$$

Here, $\Delta V/V$ and $\Delta\alpha/k$ are velocity and attenuation changes, respectively, σ and ε_r are conductivity and relative permittivity of liquid, respectively, ' denotes sample parameter, ε_0 is the dielectric constant of free space, K_S^2 and ε_P^T are the electromechanical coupling factor and the effective permittivity of the crystal used, and ω is angular frequency. From eqs (1) and (2), circular equations are derived by eliminating σ' or ε_r'. The chart is shown in **Fig. 3**. As the reference liquid in this study is the olive oil, the relative permittivity of the olive oil was used. The electromechanical coupling factor is calculated from the phase velocities of open and short surfaces, when the reference liquid is loaded onto the sensor. Therefore, the factor was derived for the olive oil. Using the chart, liquid properties can be evaluated.

The experimental results for the used and new engine oils are plotted on **Fig. 4**. We understand that dielectric constant and conductivity of the used engine oil increase together compared with new engine oil. It is thought that the dielectric constant of the used engine oil increased by various factors such as the alien substance mixture and oxidation by the heating to oil. In addition, factors such as the water mixture are thought about conductivity having risen. By this experiment, we were able to distinguish the used engine oil from new engine oil by an electrical characteristic of the engine oil.

On the other hand, we cannot obtain the differences from the measured results using the short channel. As the viscosity of the engine oil is the almost same with the olive oil, it is reasonable. When the change of viscosity is detected using the SH-SAW sensor, optimum selection of the reference liquid is required.

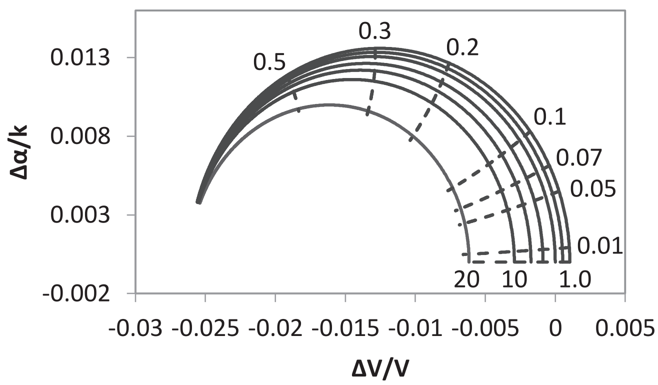

Fig. 3. The permittivity – conductivity chart.

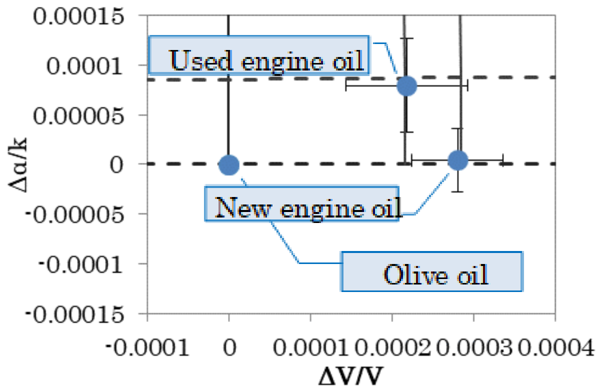

Fig. 4. Evaluation of used and new engine oil using the permittivity – conductivity chart.

5. Conclusions

It was intended to evaluate deterioration of the engine oil using the SH-SAW sensor in this study. It followed that the dielectric constant and the conductivity increased together by using engine oil when we examined the electrical properties of used engine oil and new engine oil. In this way, we were able to distinguish the used engine oil from new engine oil by an electrical characteristic of the engine oil. We can exchange engine oil at appropriate time and connected for increase in oil exchange interval by monitoring the engine oil using the sensor. In addition, we can prevent engine trouble by the use of the deteriorated engine oil.

References

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