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Influence of SH-SAW sensor frequency for engine oil degradation evaluation

エンジンオイル劣化評価における SH-SAW センサ周波数の影響

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1. Introduction

Engine oil deteriorates when impurities are mixed and overheated depending on the operating time and the number of operations. Continuing to use degraded engine oil shortens the life of the system, so measuring engine oil has become an important issue.

A shear horizontal surface acoustic wave (SH-SAW) sensor has the advantages of high sensitivity, low cost, small size, and wireless use, which makes it possible to use the SH-SAW as a simple and highly sensitive oil sensor. In previous research, engine oil degradation has been evaluated using a 50MHz SH-SAW sensor[1]. The sensitivity of the SH-SAW sensor depends on the frequency. In this paper investigate the frequency dependence of the SH-SAW sensor for evaluating engine oil degradation using a SAW sensor.

2. SH-SAW sensor device

The SH-SAW can propagate through the solid-liquid interface without radiating longitudinal waves into the liquid (see **Fig. 1**) **Figure 2** shows the SH-SAW sensor device used in this paper. The sensor device was consisted with two SAW delay lines with interdigital transducers (IDT). One propagation surface was shorted with the gold evaporated film. The other has a free surface area, where the piezoelectric substrate is in direct contact with liquids. When a sinusoidal signal was fed to the input IDT (see **Fig. 3**), the SH-SAW was generated from the IDT. The SH-SAW propagated through the solid-liquid interface and was converted to the sinusoidal signal at the output IDT. The SH-SAW was affected by both the electrical and mechanical properties of the liquid on the open channel and the mechanical property of the liquid on the shorted channel. The mechanical property is obtained from the shorted channel. When the electrical property of the liquid is measured, the advantage of the SH-SAW sensor is the simultaneous detection of the mechanical and electrical properties of the liquid, and the measurement with a small amount of liquid.

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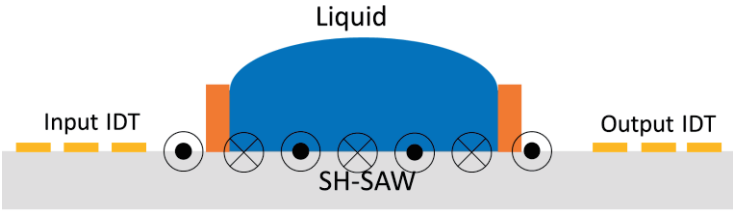


Fig1: SH-SAW propagating through a solid-liquid interface

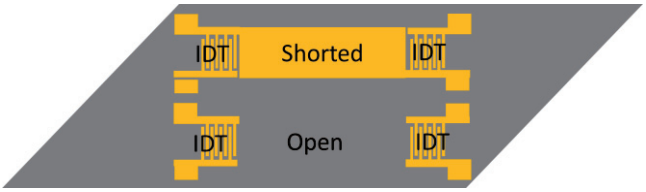


Fig2: Device used

3. Measuring method

The experimental system used in this study is shown in Fig. 3. The center frequencies of the used SH-SAW device were 30 and 155MHz. The reference was the signal from the signal generator. The phase difference between the reference and the output signal from the sensor, and amplitude were measured using a vector voltmeter. The velocity change (ΔV/V) and the attenuation change normalized by the wave number (Δα/k) were calculated from the phase difference and amplitude, respectively. The measurement system was controlled by a personal computer (PC).

To simulate the degradation of the engine oil, moisture and iron powder were varied. Also, to investigate the influence of the temperature, the engine oil was heated.

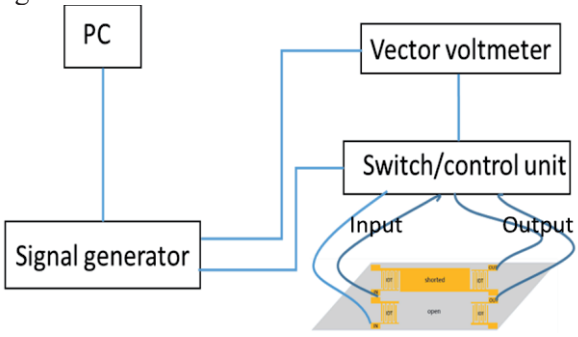


Fig.3 Experimental system used in this paper

4. Results and discussion

4.1 Comparison of new and used engine oils

New engine oil and the used engine oil were measured. The reference liquid was an olive oil. The results are shown in **Fig. 4**. The results of 50 MHz were from Ref. 1. As the differences between the new and used oils increases with the frequency, the SH-SAW sensor with higher frequency is better to measure the used engine oil.

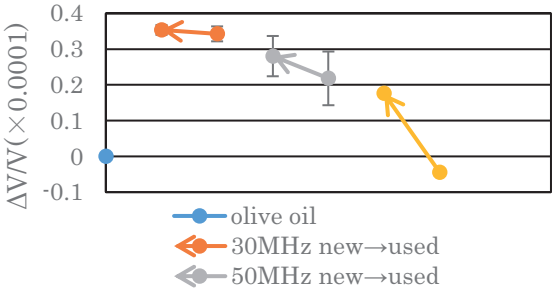


Fig.4 Velocity change between new and used engine oils

4.2 Heat degradation of engine oil

Temperature and time of the engine oils heated were heated at 100 ˚C, and 1000 and 3000 hours. In this paper, the electrical property was focused. **Figure 5** shows the results of velocity and attenuation changes. The arrow indicates the passage of time. From the figure, it is found that 1) the attenuation change decreases with time and the standard deviation of the velocity shift is large. Improve of the measurement method is necessary.

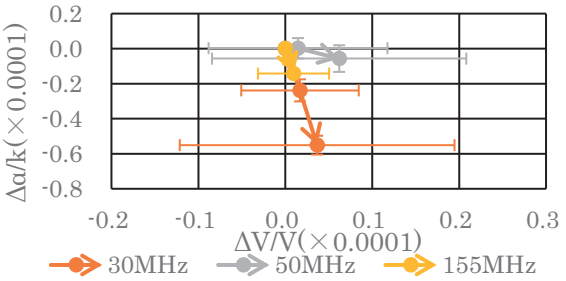


Fig.5 Velocity and attenuation change due to heat degradation

4.3 Oil heat degradation

The influence of the moisture in the engine oil was discussed. In previous reseach[1], the influence of the mechanical property change is not significant. In this paper, we discussed about the electrical property changes. **Figure 6** shows the velocity and attenuation changes, when 1wt% and 10wt% pure water are mixed and stirred with the new engine oil. The arrow indicates the increase in moisture. It can be seen that 30MHz changes greatly. This is because the sensor sensitivity to conductivity increases as the frequency decreases.

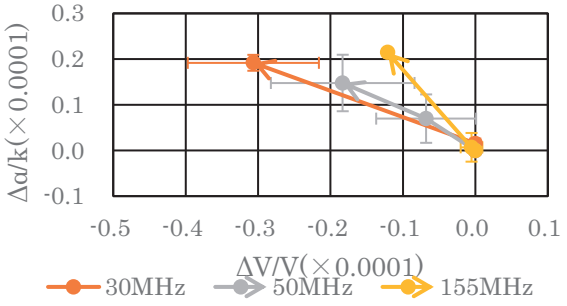
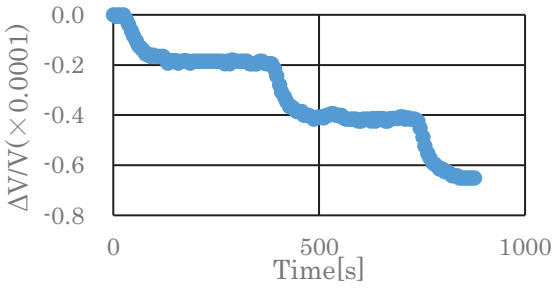


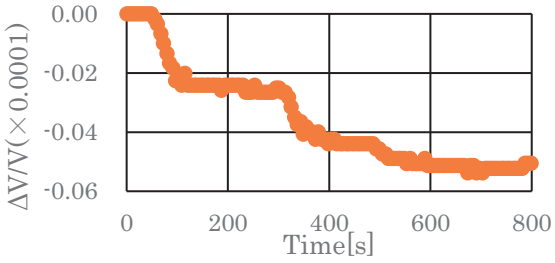
Fig.6 Velocity and attenuation change due to moisture mixing

4.4 Influence of iron powder in engine oil

The iron powder of 1 mg was mixed into the new engine oil three times. The results of the velocity change for the electrical property are shown in Figs. 7(a) and 7(b). The influence of the iron powder for the 30 MHz SH-SAW sensor is larger than it for the 155 MHz SH-SAW sensor.



(a)



(b)

Fig. 7 Influence of the iron powders in engine oil. (a) 30 MHz and (b) 155 MHz.

5. Conclusion

In this paper, the influence of the SH-SAW sensor frequency for the degradation of the engine oil is discussed. When the change between the new and used engine oil, the higher frequency sensor is better. However, to evaluate heat degradation and influence of iron powder, the low SH-SAW sensor must be used. The results indicate that the SH-SAW sensor frequency should be selected for the purpose of the measurements.

References

1. S. Kobayashi. et al. Jpn. J. Appl. Phys. 57, 07LD09 (2018).