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Piezosensors for Monitoring Degradation of Automotive Engine Oil

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Abstract

Effect of heating times on piezoelectric sensing of engine oil has been investigated with different heating times (0, 15, 30, 45 and 60) min. Sensing signals (piezoelectric) characterized and achieved by using transducer which transmits a mechanical waves towards the glucose solution cell, and then the receptor received the attenuated signals. The range of operating frequencies was (950 kHz - 50MHz), the results of measurement which included recording the resonance frequencies (in the first order) for all prepared samples. The results showed that the resonance frequency shifted to the higher values (from 12MHz to 26MHz) for heating times (from 0 to 60 min) of engine oil.

Key words: engine oil, piezoelectrical properties, resonance frequency, Damping Coefficient.

BACKGROUND

Internal combustion engines in automobiles and other vehicles can only perform efficiently if there is proper lubrication between moving parts. Automotive engine oil is a mixture of base stock, and a number of additives which improve the operational properties of the lubricating oil [1]. Engine oils are susceptible to degradation by oxygen, increased temperature, and shear stress. The degradation of oil is very complex process and affects mainly additives and afterwards, oxidation of the base stock leads to formation of different acidic products, especially carbonic acids, and polymerization processes. The reduced lubrication capabilities caused by inadequate oil viscosity will damage the engine [2]. Thus, there is a need to design a sensor device which can tell us about chemical oil quality, by monitoring these directly in the oil. A variety of sensor devices have been proposed to monitor the degradation based on different parameters such as viscosity [3], conductivity [4], and acidity [5]. Further improvements were carried out by introducing molecular recognition properties in sensitive layers to determine the chemical quality of engine oil in gas or liquid phase by employing mass sensitive transducers [6-8]. Recently, dielectric spectroscopy has also been employed to detect the age of used engine oil [9]. In this paper, we have analyzed the piezoelectric properties of Engine oil.

EXPERMINTAL WORK

The material used in this paper is (super diesel engine oil meets API service CF, produced and packaged by petromin corporation, Saudi Arabia) at 90 ^{o}C heating temperature with different heating times.

The effect of heating times (0, 15, 30, 45 and 60) min on piezoelectric sensing of engine oil was measured. The setting used in this paper include a standard two piezo-crystals (Model number: 3B12+9.0EAWC, Type: Piezoelectric Ceramics, Material: Piezoceramics, Metal type: Brass, Electrode form: (Thin) Diode, Connection terminal: Soldier wire or not, Parameter value: (D=12mm, T=0.15mm and f=9 kHz)) located tightly on the copper foil as a diaphragm shown in Fig. (1).

Fig. 1: Image of piezo-crystal used in this work.

RESULTS

The resonance frequency can be determined by measuring the output voltage as a function of frequency as shown in Fig. (2), we can observed that the resonance value varied as the frequency sweept from 950 kHz to 50 MHz at different heating times and fixed teamperature at 90 ^{o}C, this varied can be due to a number of reasons, such as humidity, atmospheric pressure and mechanical loading. The effect of heating times on resonance frequency can be seen in Fig. (3).

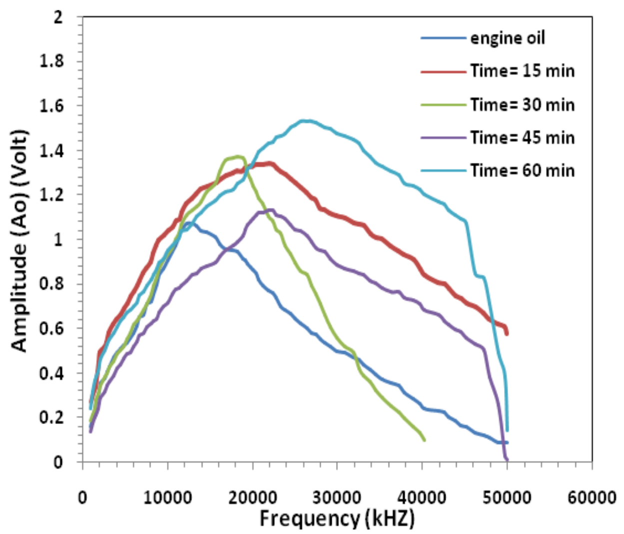


Fig. 2: The resonance frequency of engine oil at different heating times and 90 °C heating temperature.

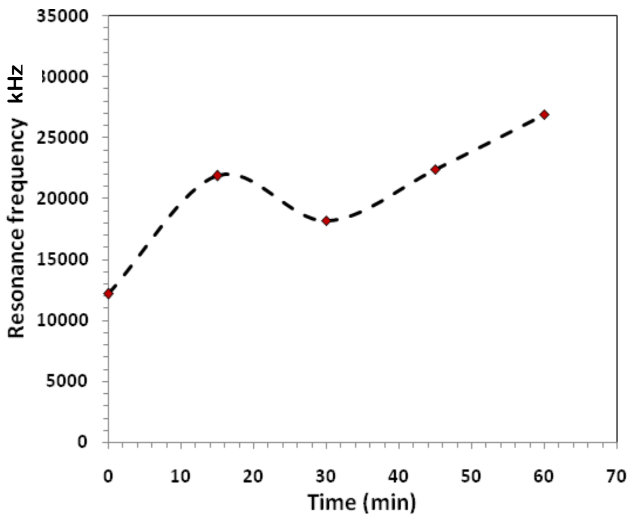


Fig. 3: Effect of heating times on resonance frequency of engine oil.

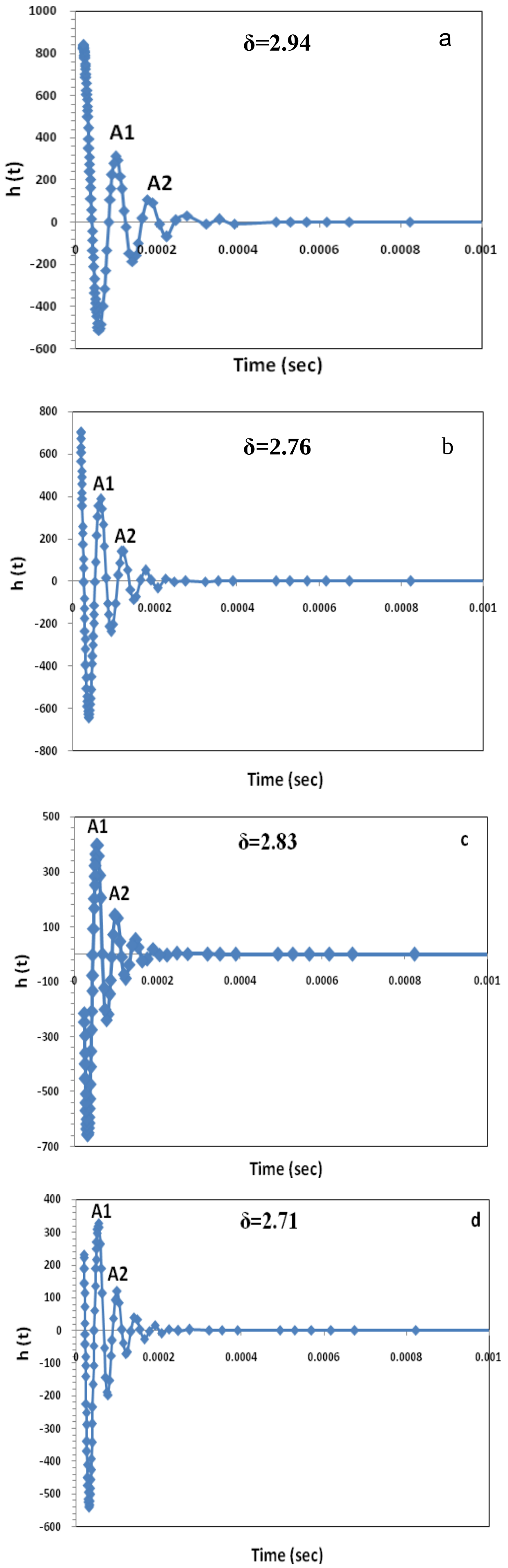
The damping coefficient (δ_D) can be calculated using the relation [10]:

$$h(t) = A_o \exp(-t/\tau) \sin(\omega t) \qquad (1)$$

where:
(A_o) is the amplitude at resonance,
(t =1/ f), (f) is the frequency,
($\omega = 2\pi f$),
(τ) is the resonance time.

Fig. (4) (a, b, c, d and e) shown the damping behavior of the wave for different heating temperature. The damping coefficient (δ_D) of the water solution at different heating times were carried out from the graph and using the relation [10]:

$$\delta_D = A_1/A_2 \qquad (2)$$



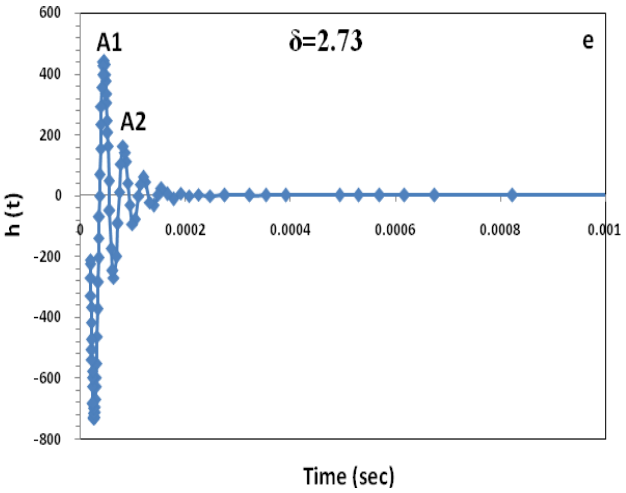


Fig. 4: Relation between the time of resonance and damping coefficient for engine oli at 90 °C with different heating times: a- engine oil, b-15 min, c-30 min, d-45 min and e- 60 min.

The shift of resonance frequency between the incident (reference) signal and that tramsmitted from engine oil at different heating temperature addition are shown in Fig. (5) (a, b, c, d and e), it is clearly that the large shifting vanish with increasing the source frequency.

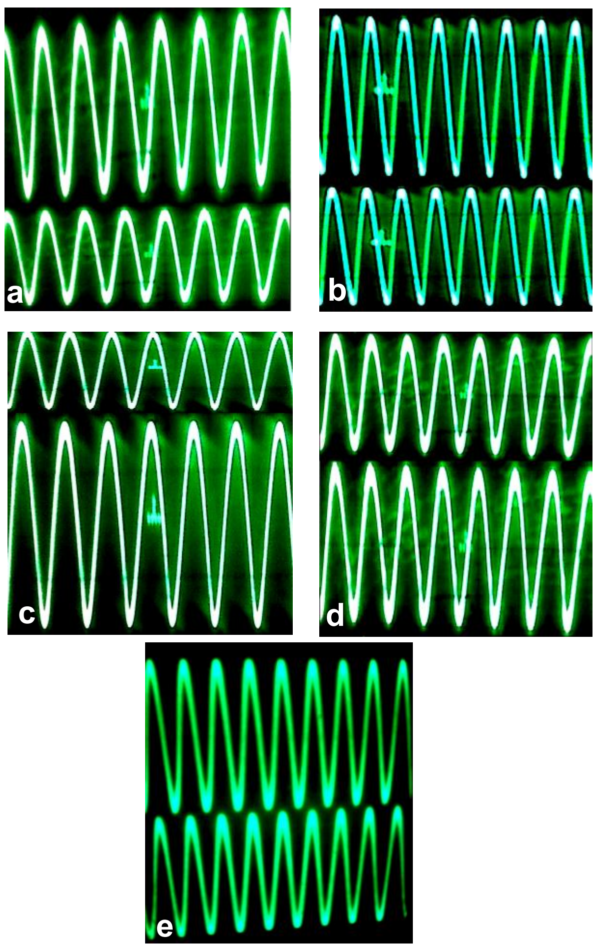


Fig.5: The incidint frequencies (upper) and the sensing frequencies (lower) by the engine oil at different heating times: a- engine oil, b-15 min, c-30 min, d-45 min and e- 60 min.

The characteristic (priciple) frequency can be calculated depending on the band width and the quality factor as in relation [11]:

$$B = f_e / Q \qquad (3)$$

Where:
f_e: the characteristic frequency.
Q: the quality factor.

The acoustic is traveling through the engine oil with velocity depending on the material addition of the water solution and on the characteristic frequency, and then the velocity could be evaluated using the relation below [11]:

$$t = \lambda/2 = V_s/2f_e \qquad (4)$$

where
t = The plate thickness,
V_s= The velocity of sound.

The quality factor was esteemed by using the relation [12]:

$$Q = \pi / \ln\delta \qquad (5)$$

As we observed the value of the quality decrease when the resonance frequency increase, our results were tabulated in the table (1).

Table (1): The result of piezoelectric properties.

Heating times (min)	f_o (kHz)	Band width (kHz) (B)	Dam-ping coeff. (δ)	Quality factor (Q)	Surface Acoustic wave velocity (V_s)	Characteristic frequency (fe) (kHZ)
Engine oil	12185.5	758.14	2.94	2.90	3398.23	2205.84
15	18187.3	951.01	2.76	3.08	4516.12	2931.48
30	21885.7	972.43	2.83	3.00	4507.58	2925.93
45	22415.7	800.43	2.71	3.13	3871.37	2512.96
60	26909.9	1084.89	2.73	3.11	5213.83	3384.37

CONCLUSION

In this paper, effect of heating times on piezoelectric sensing of engine oil has been investigated with different heating times (0, 15, 30, 45 and 60) min. The results showed that the resonance frequency shifted to the higher values (from to 12 MHz to 26MHz) for heating times (from 0 to 60 min) of engine oil.

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