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doi:10.15199/48.2018.04.29

The Measurement Technique of Surface Tension Using Inductance Values

Abstract. *The objectives of this study were to examine correlations of inductance values on surface tension of water and to develop other techniques for measuring the surface tension of water using inductance values. The design was based on the variation of inductance values by moving the Ferrite cores that was connected with a conductor plate on water surface when conducting weight counterbalance. The results found that at the surface tension of 66.24 mN/m –71.20mN/m with the inductance values of 0.5mH, 1.0mH and 1.5mH coils.*

Streszczenie. *Celem pracy było zbadanie korelacji wartości indukcyjności naprężeń powierzchniowych wody oraz opracowanie nowych metod pomiaru naporu powierzchniowego wody przy użyciu wartości indukcyjności. Projekt został oparty na zmianie wartości indukcyjności rdzenia ferrytowego, który połączono z płytą przewodową na powierzchni wody przy równoważeniu wagi. Wyniki wykazały, że przy napięciu powierzchniowym 66,24 mN/m -71,20 mN/m indukcyjnoś cewek 0,5 wynosiła0.5 mH, 1.0 mH i 1.5 mH.* ***Pomiary naprężeń powierzchniowych metodą indukcyjną***

Keywords : surface tension, Inductance, measurement
Słowa kluczowe : napięcie powierzchniowe, Indukcyjność, pomiary

Introduction

Surface tension is a natural phenomenon that occurs on the surface of a liquid in contact with another liquid or a solid. The surface molecules bound over the two surfaces are called cohesive force or surface tension. In general, the surface tension value is used to explain chemical behavior of liquids and considered an index to monitor quality of industrial products such as detergent products, cosmetics, medicines, lubricants, pesticides, and food products. In addition, the occurred surface tension has an effect on the process of industrial procedures such as quality examination of production process in distillation and extraction.

Measurement techniques of surface tension of liquids can be classified as follows: 1) direct measurement using a microbalance which consists of Wilhelmy Plate and Du Noüya Ring's techniques, 2) measurement of capillary pressure which consists of Maximum Bubble Pressure and Growing Drop, 3) capillary force and gravity force which consists of Capillary Rise and Drop Volume, 4) gravity-distorted drop which consists of Pendant Drop and Sessile Drop, and 5) reinforced distortion of drop which consists of Spinning Drop and Micropipette.

Each measurement has its limitations as follows: Wilhelmy Plate andDu Noüya Ring's techniques create difficulty in calibrating the ring's weight and the plates dipped into a liquid, and reduce accuracy when applying to the interface of 2 liquids or either liquid or both with viscosity. When measuring surface tension with capacitance values, the capacitance values are very sensitive to the temperature. This is because the dielectric is the air. When the temperature changes, the dielectric values of the air also change. The capacitance values have low frequency response. The oxides formed on the conductor plates have an effect on the capacitance values. This results in the difficulty in calibrating the ring's weight and the plates dipped in the liquid and less accuracy when applying to the viscous liquid surface. The techniques of Maximum Bubble Pressure, Capillary Rise, Drop Volume and Pendant drop are not suitable for measuring liquids with high viscosity and molten metal with sensitivity to vibration.

The main purpose of these techniques is to examine the surface tension values of liquids. However, these techniques provide limitations. For example, the measurement equipment is expensive, and the experiment must be conducted in a lab.

Concerning these problems, this experimental study was to examine the equipment used for measuring the surface tension of liquids by using inductance values at the surface tension of 71.20 mN/m - 64.47mN/m and to develop techniques for measuring the surface tension of water by using inductance values. The method used for this study was simple. The equipment used for measuring the surface tension of liquids was low cost, highly responsive to low and high frequency and could be tested both in and outside the laboratory.

Experiments

This experimental research was based on the principle of inductor to analyze data. The measurement of surface tension of water using inducer can be explained by measuring the electrical properties occurred. This experiment used 18 AWG. The 18 AWG is used in general applications and suitable for measuring the surface tension of water using conductors as inducer. Coils around the sphere are a virtual conductor. And inductive coils collect electrical energy. The electric field in the inductive coils is similar to the electric field occurred. The distance of the ring exposed to water has an effect on the variation of inductance values.

Samples

The surface tension has specific values varying by types of liquids. For example, at 20 degree Celsius, there are various surface tension units of liquids. Apart from this, the surface tension varies depending on temperature. When the temperature rises, cohesion of liquid molecules is reduced. This results in low surface tension values. Research scopes were as follows:

1) The sample used in this study was water
2) The variables were as follows: the dependent variable consisted of the inductance values, and the independent variable consisted of temperature of water at room temperature and at 30, 40, 50, 60, and 70 Degree Celsius.

Equipment used to collect data

From the experiment, a design of the shape of the surface tension measuring device was created. This device affected variations of electrical properties associating with inductance values in various aspects such as size, shape and the number of coils. The shape and features used for testing surface tension of water using inducer was designed by using split-end anode and cathode as shown in Figure 1.

Surface tension is the force that occurs on the area that the surface of a liquid is in contact with another liquid or a solid surface with sufficient force to bond molecules. The relative size with adhesive force and cohesive force creates a thin sheet that is able to resist tension force. So, when the sheet exposed to the surface is pulled, the surface tension values change. As a result, the inductance values increase in proportion to the surface tension values. The inductance values are related to the surface tension values. The equations are as follows:

$$L = \frac{N^2 \mu A}{l} \qquad (1)$$

According to the obtained variation of inductance values, two difference values are calculated in equation 2. These two difference values are the difference of the ring's weight at two contacting points and the difference of two inductance values.

$$\gamma = \frac{\left[\frac{N^2 \mu A}{L}\right] w - (mp + mg)}{a} \qquad (2)$$

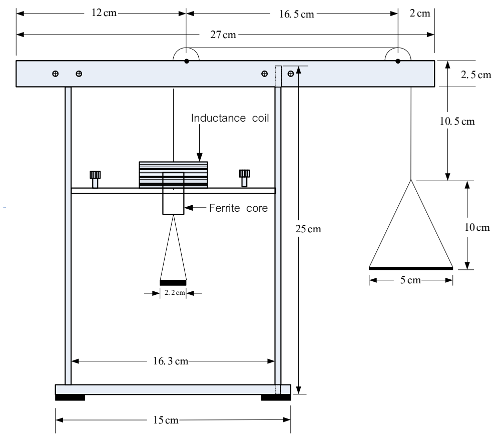

Fig. 1. Experimental equipment used for measuring the surface tension of water with inducer

Fig. 2. Various sizes of coil wiring of 0.5mH, 1mH and 1.5mH

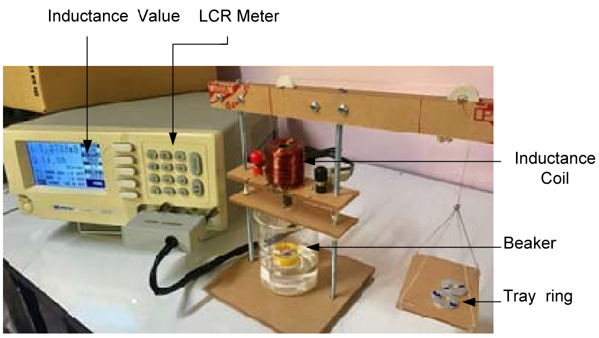

Fig. 3. Experimental installation of inductance value measurements

Equipment organizing processes were as follows:

1. Study types and current techniques of surface tension measurement.
2. Analyze advantages and disadvantages of each technique.
3. Study the principle of inductive coils to be used for measuring the surface tension of liquids.
4. Design and build a measuring equipment using inductance values and an equipment used in the experiment.

Results

The experiment was conducted to examine the correlation coefficients of the inductance values of the coil wiring (L) at surface tension (ST) of 64.47mN/m-72.75mN/m of Various sizes of coil wiring with 3 different diameters; 0.5mH, 1mH and 1.5mH, and at water level of 98 ml. LCR meter will be used to measured the inductance values of the coil wiring. The LCR meter will read the data of the variation of the inductance when the ring is weighted. The results were shown in Fig. 6

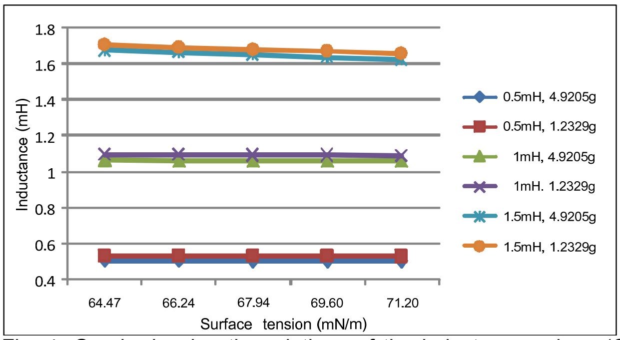

Fig. 4. Graph showing the relations of the inductance values (C), weight of the ring, and surface tension values (γ)

According to the inductance values of 0.5 mH. coil wiring with water, at the surface tension value of 64.47mN/m, the highest inductance value at all weight ranges was 0.50517–0.53492mH. The inductance values decreased when the surface tension values increased. And at the surface tension value of 71.20mN/m, the lowest inductance value was 0.50120–0.52940mH. The results showed that the surface tension of water directly affected the inductance value as the surface tension held the distance of the Ferrite core.

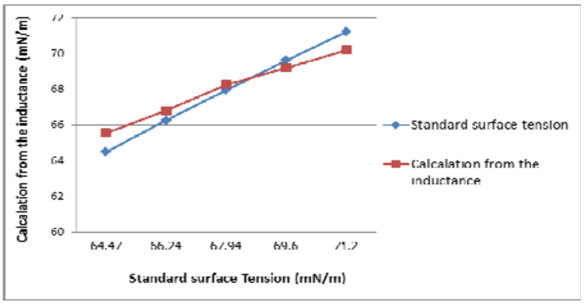

Fig. 5. Inductance values of 0.5 mH coil wiring

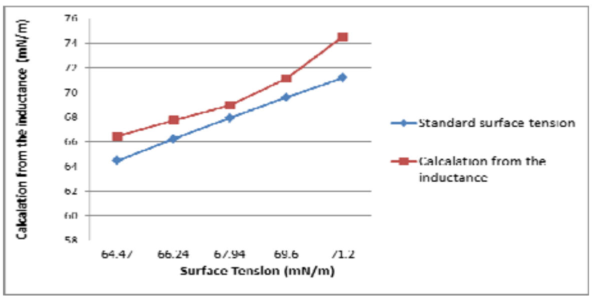

Fig. 6. Inductance values of 1 mH. coil wiring

According to the inductance values of 1mH coil wiring with water, at the surface tension value of 64.47mN/m, the highest inductance value at all weight ranges was 1.06543–1.09567 mH. The inductance values decreased when the surface tension values increased. And at the surface tension value of 71.20mN/m, the lowest inductance value was 1.06019–1.09080mH. The results showed that the surface tension of water directly affected the inductance value as the surface tension held the distance of the Ferrite core.

According to the inductance values of 1.5mH coil wiring with water, at the surface tension value of 64.47mN/m, the highest inductance value at all weight ranges was 1.67580–1.70912mH. The inductance values decreased when the surface tension values increased. And at the surface tension value of 71.20mN/m, the lowest inductance value was 1.62481–1.65994mH. The results showed that the surface tension of water directly affected the inductance value as the surface tension held the distance of the Ferrite core.

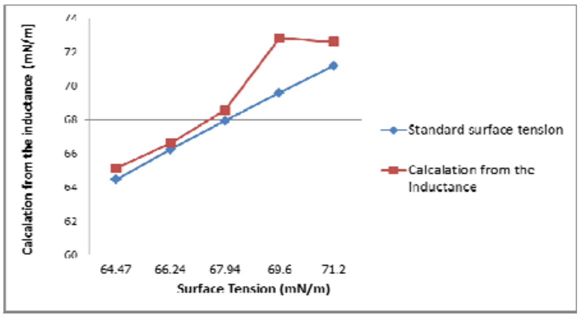

Fig. 7. Inductance values of 1.5 mH coil wiring

Conclusions

The measurement of surface tension using inductance values was summarized as follows:

The surface tension value of water obtained from the inductance values of 0.5mH. Coil showed 3 ranges of proper weight of the ring as follows: with 1.2329g-2.4532g ring, the surface tension value was 68.25mN/m. With 1.2329g-2.4532g ring, the surface tension value was 67.94mN/m. The deviation compared to standard value was 0%.With 2.4532g -3.6947g ring, the surface tension value was 71.31mN/m. The deviation compared to standard value was 0.08%.And with 3.6947g-4.9205gring, the surface tension value was 69.68mN/m. The deviation compared to standard value was 0.06%.

The surface tension value of water obtained from the inductance values of 1mH. Coil showed 3 ranges of proper weight of the ring as follows: with 1.2329g-2.4532g ring, the surface tension value was 68.97mN/m. The deviation compared to standard value was 0.75%. With 2.4532g-3.6947g ring, the surface tension value was 66.75mN/m. The deviation compared to standard value was 0.38%.And with 3.6947g -4.9205g ring, the surface tension value was 67.48mN/m.The deviation compared to standard value was 0.34%.

The surface tension value of water obtained from the inductance values of 1.5mH. Coil showed 3 ranges of proper weight of the ring as follows: with 1.2329g-2.4532g ring, the surface tension value was 66.62mN/m. The deviation compared to standard value was 0.29%.With 2.4532g-3.6947g ring, the surface tension value was 69.22mN/m. The deviation compared to standard value was 0.27%.And with 3.6947g-4.9205g ring, the surface tension value was 67.74mN/m.The deviation compared to standard value was 0.11%.

The surface tension value of ethyl alcohol obtained from the inductance values at 20degree Celsius showed that the best surface tension value was obtained by 1mH. Coil when compared to 3 sizes of coil as follows: with 1.2329g-2.4532g ring, the surface tension value was 22.47mN/m, The deviation compared to standard value was 0.38%. With 2.4532g-3.6947g ring, the surface tension value was 22.55mN/m. The deviation compared to standard value was 0.56%. And with 3.6947g-4.9205g ring, the surface tension value was 22.15mN/m. The deviation compared to standard value was 0.34%.

The surface tension value of acetone obtained from the inductance values at 20degree Celsius showed that the best surface tension value was obtained by 0.5mH. Coil when compared to 3 sizes of coil as follows: with 1.2329g-2.4532g ring, the surface tension value was 23.42mN/m. The deviation compared to standard value was 0.59%. With 2.4532g-3.6947g ring, the surface tension value was 24.31mN/m. The deviation compared to standard value was 1.27%. And with 3.6947g -4.9205g ring, the surface tension value was 23.15mN/m and the deviation compared to standard value was 1.17%.

According to the surface tension values of water obtained from the inductance values, it was found that the 0.5 mH coil was capable of measuring the surface tension well at 60 degree Celsius with 3.6947g-4.9205g ring. The deviation compared to standard value was 0.07%.The 1mH coil was capable of measuring the surface tension well at 50 degree Celsius with 3.6947g-4.9205g ring. The deviation compared to standard value was 0.34%.And the 1.5 mH coil was capable of measuring the surface tension well at 70 degree Celsius with 2.4532g-3.6947g ring. The deviation compared to standard value was 0.27%.

The results of this study can help create measurement techniques of surface tension of liquids using inductance values.The operation of the equipment relied on variation of the distance of the ring that exposed to water surface. The transition distance corresponded to the liquid surface tension measured. The obtained inductance values were calculated to find the surface tension values. This method is an appropriate method for measuring the surface tension of liquids.

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