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A Novel of Surface Tension Measurement

Abstract. *A new surface tension measurement is presented. The design used variations of relations of distance between parallel conductive plates (d) and the surface tension values (γ). This experiment was conducted by measuring the electrical capacitance values which varied due to the surface tension of water at round-shaped parallel conductive plates with 3 in diameters at the surface tension of 64.47mN/m - 72.75mN/m*

Streszczenie. *Przedstawiono nową metode omiaru napięcia powierzchniowgo bazująca na pomiarze podległości miedzy dwoma przewodzacymi płytkami. Pomiarowi podlega pojemność między tymi płytkami.* ***Nowa metoda pomiaru napięcia powierzchniowego***

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

Introduction

Surface tension is a natural phenomenon that occurs on the surface of liquid in contact with another liquid or solid surface. The surface molecules bound over the two surfaces. This is called cohesive force or surface tension [1]. In general, the surface tension is used to explain chemical behavior of liquids acts as an index to monitor the quality of industrial products such as detergent products, cosmetics, medicines, lubricants, pesticides, and food products. In addition, the surface tension that occurs has an effect on steps of industrial procedures such as distillation and extraction [2,3] including the examination of the quality of production process.

The measurement techniques of surface tension of liquids can be classified as follows; Group 1: Direct Measurement Using a Microbalance such as Wilhelmy Plate [4] and Du Noüya Ring [5]. Group 2: Measurement of Capillary Pressure such as Maximum Bubble Pressure [6] and Growing Drop [7]. Group 3: Capillary Force and Gravity Force such as Capillary Rise [8] and Drop Volume [9]. Group 4: Gravity-Distorted Drop such as Pendant Drop [10] and Sessile Drop [11]. And group 5: Reinforced Distortion of Drop such as Spinning Drop [12] and Micropipette [13].

Each group has its limitation as follows; Group 1: Direct Measurement Using a Microbalance is not suitable for measuring molten metal and surfactants. Group 2: Measurement of Capillary Pressure is not suitable for measuring liquids with high viscosity and molten metal. Group 3: Capillary Force and Gravity Force is not suitable for measuring liquids with high viscosity and molten metal. Group 4: Gravity-Distorted Drop is not suitable for measuring liquids with high viscosity. And group 5: Reinforced Distortion of Drop is not suitable for measuring liquids with high viscosity. [14,15]

The principal objective of the aforementioned measurement techniques was to examine the surface tension of liquids. Due to those measurement limitations, the researcher proposed the measurement techniques of the surface tension of water with parallel conductive plates by using the variation of relations of the distance between the parallel conductive plates (d) and the

surface tension (γ) as the basis for measuring the surface tension of water. The surface tension of water or liquids to be tested will have direct effects on the variations of the distance between the parallel conductive plates. The techniques for testing the surface tension of water with the parallel conductive plates were analyzed from the limitations and the advantages and disadvantages of each technique group. The aforementioned limitations of those techniques did not have any effects on the researcher's measurement method.

Experiments

The design of the parallel conductive plates was invented from a brown phenolic printed circuit board (Phenolic). The phenolic circuit boards are used in general work to reduce costs. This is because they are cheaper than other printed circuit boards made from other materials. The parallel conductive plates consisted of two round-shaped conductive plates which were parallel to each other. The conductive plates will store electrical charge or electrical energy. The electric field between the parallel conductive plates had a virtual state to the electric field occurred. When changing the distance between the parallel conductive plates, it results in the variation values of the capacitance values. The capacitance value can be calculated from the Eq.1 [16,17]

$$C = \varepsilon_0 \varepsilon_r \left[\frac{A}{d} \right] \qquad (1)$$

where C is the capacitance (farads), A is the area of the parallel conductive plates, d is the distance between the conductive plates. Both ε_0 which is 8.854×10^{-12} and ε_r which is 1.0054 of air are permittivity values (Permittivity). From the above equation, the capacitance is in direct proportion to the area and inverse proportion to the distance between the conductive plates. [18,19]

$$C = \varepsilon_0 \varepsilon_r \left[\frac{A}{\frac{mp + mg + \gamma l}{w}} \right] \qquad (2)$$

From Fig. 1, the parallel conductive plates will be measured the electric capacitance values that occurs when changing the distance between the two conductive plates. The distance between the conductive plates are associated with the surface tension of the water as in Eq. 2. This explains that the surface-tension values (γ) will affect the charge values (C) occurring when mp is the mass of the plates, mg is the mass of the ring touching the surface of water. γ is the surface tension of water, l is the length of the ring touching the water surface, w is the total mass of the ring when weight counterbalance and the weight of the ring tray, C is the capacitance values.

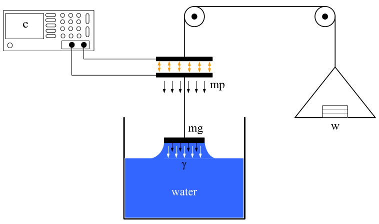

Fig. 1. The principle of techniques of electrical capacitance measurement of the parallel conductive plates

From Fig. 2, it shows the round-shaped conductive plates used for the experiment. Fig. 3 explains the installation of two conductive plates in parallel position. When used, they can change the distance between the conductive plates along with the surface tension of the liquids when weight counterbalance is done. The changes of increase or decrease in the capacitance value rely on the surface tension of the liquid.

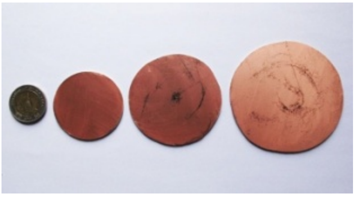

Fig. 2. Three sizes of round-shaped PCB

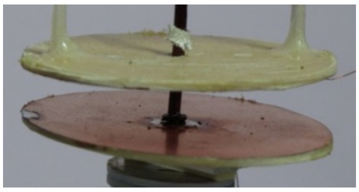

Fig. 3. Invented plate installation. (Printed Circuit Board)

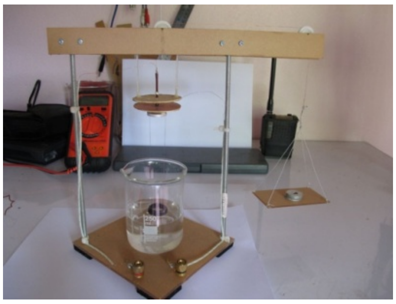

Fig. 4. Experimental equipment

After completing the process of invention along with Fig. 4, the parallel conductive plates were checked for accuracy and defects which occurred on the two plates by cleaning the surface of PCB to remove unwanted copper scraps as the copper scraps on the surface of the conductive plates can affect the capacitance values, and determining the designed distance. All of these factors can have effects on efficiency of measurement.

This experiment studied the relations of the electrical capacitance values of the parallel conductive plates at the surface tension of 64.47mN/m -72.75mN/m. There were 3 sizes of conductive plates with 6 different levels of surface tension; the diameter (Ø) of 54.7mm at the distance between the plates of 8mm, (Ø) of 61.4mm at the distance between the plates 15mm, and (Ø) 76.95mm at the distance between plates 10mm. The devices used in this experiment were a GW Instek LCR Meter: LCR 871 for reading the electrical capacitance values, and an LT400G LEGA thermometer. The parallel conductive plates were connected to the anode and cathode, and the ground line was connected to LCR meter before a measurement. The LCR meter was set to be at 1.0KHz, and the voltage values of 1.0Vp-p and 0V were set to the ground line. This device was used for measuring the capacitance values of the surface tension of water that varied. The experimental installation was shown in Fig. 5. The invented devices were set to be accurate for accuracy in reading values and for minimal errors.

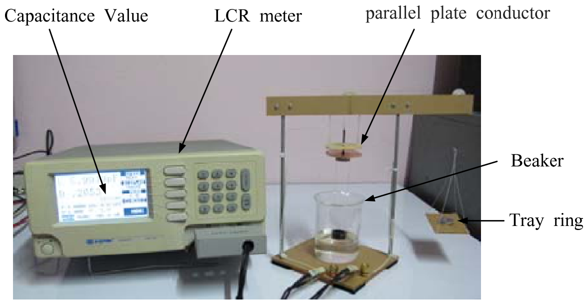

Fig. 5. Experimental installation of the capacitance value measurement

Results

The experiment was conducted to examine the correlation coefficients of the capacitance values of the conductive plates (C) at surface tension (ST) of 64.47mN/m - 72.75mN/m of the parallel conductive plates with 3 different diameters; (D1) 54.7mm, (D2) 61.4mm, and (D3) 76.95 mm, and at water level of 98 ml. LCR meter will be used to measured the capacitance values of the parallel conductive plates. The LCR meter will read the data of the variation of the capacitance when the ring is weighted. The results were shown in Fig. 6

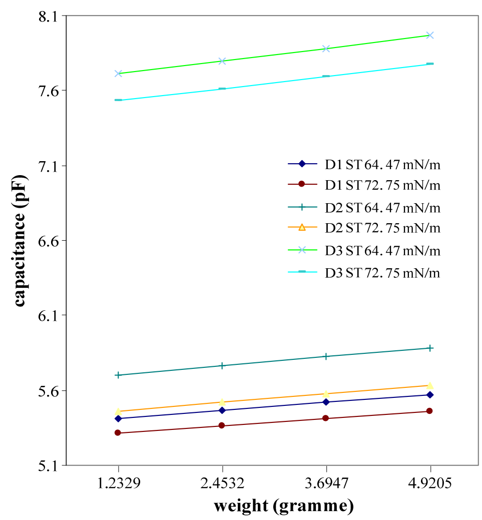

Fig. 6. Graph showing the relations of the capacitance values (C), weight of the ring, and surface tension values (γ)

Linear response results of the capacitance values of the parallel conductive plates with 3 different sizes, measured at the surface tension of 64.47mN/m – 72.75mN/m. The capacitance values of the parallel conductive plates with (D1) 54.7mm were between 5.3110pF – 5.5729pF. The capacitance values of the parallel conductive plates with (D2) 61.4mm were between 5.4625pF – 5.8793pF. For the parallel conductive plates with (D3) 76.95mm, the capacitance values were between 7.5298pF – 7.9669pF.

From Fig.7-9 the surface tension will be calculated from the measured capacitance by applying the Eq. 2. In Fig. 6, variation values of the capacitance and the ring weight calibration between 1.2329g – 2.4532 g are used for calculating the surface tension values. The results were shown in Fig. 7-9.

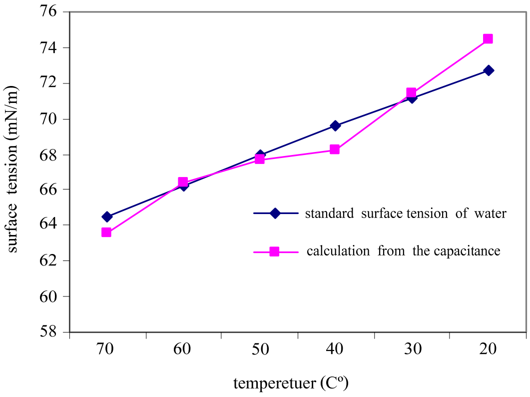

Fig. 7. Graph showing a comparison of surface tension values calculated from C comparing to the standard value at the parallel conductive plates with 54.7 mm in diameter

In Fig. 7 showing a comparison of surface tension values resulting from calculations of the capacitance values comparing to the standard value, the best surface tension value is at 66.43 mN/m, the deviation value comparing to the standard deviation is at 0.19mN/m. At the surface tension of 71.42mN/m, the deviation value comparing to the standard deviation is 0.22mN/m. At the surface tension of 67.70mN/m, the deviation value comparing to the standard deviation is 0.24 mN/m. At the surface tension of 63.955mN/m, the deviation value compared to the standard deviation is 0.515mN/m. At the surface tension of 68.23mN/m, the deviation value comparing to the standard deviation is 1.37mN/m. At the surface tension of 74.48mN/m, the deviation value comparing to the standard deviation is 1.73mN/m.

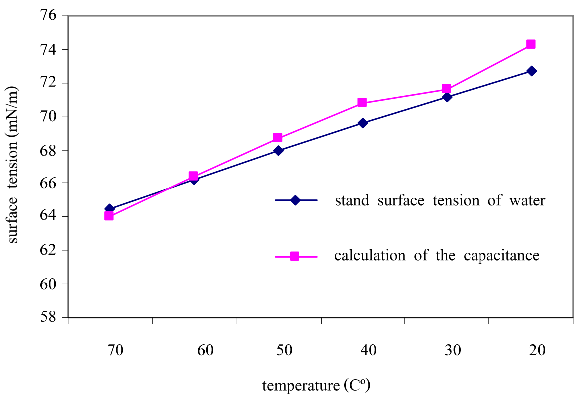

Fig. 8. Graph showing a comparison of surface tension values calculated from C comparing to the standard value at the parallel conductive plates with 61.4mm in diameter

In Fig. 8 it shows a comparison of surface tension values resulting from calculations of the capacitance values comparing to the standard value. The best surface tension value is at 66.45 mN/m, the deviation value comparing to the standard value is at 0.21mN/m. At the surface tension of 71.57mN/m, the deviation value comparing to the standard value is at 0.37mN/m. At the surface tension of 64.01mN/m, the deviation value comparing to the standard value is at 0.46mN/m. At the surface tension of 68.71mN/m, the deviation value comparing to the standard value is at 0.77 mN/m. At the surface tension of 70.78mN/m, the deviation value comparing to the standard value is at 1.18mN/m. At the surface tension of 74.27mN/m, the deviation value comparing to the standard value is at 1.52 mN/m.

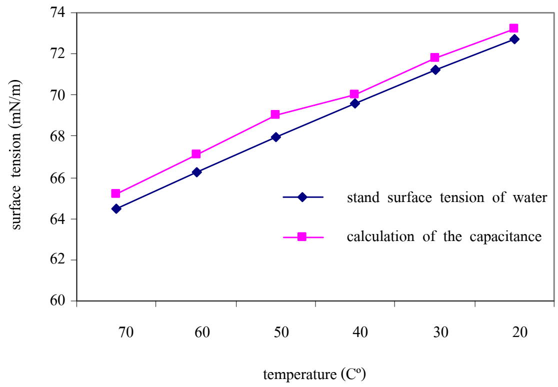

Fig. 9. Graph showing a comparison of surface tension values calculated from C comparing to the standard value at the parallel conductive plates with 76.95mm in diameter

In Fig. 9 it shows a comparison of surface tension values resulting from calculations of the capacitance values comparing to the standard value. The best surface tension value is at 70 mN/m, the deviation value comparing to the standard value is at 0.4mN/m. At the surface tension of 73.25mN/m, the deviation value comparing to the standard value is at 0.5mN/m. At the surface tension of 71.82mN/m, the deviation value comparing to the standard value is at 0.62mN/m. At the surface tension of 65.18mN/m, the deviation value comparing to the standard value is at 0.71 mN/m. At the surface tension of 67.08mN/m, the deviation value comparing to the standard deviation is at 0.84mN/m. At the surface tension of 69.021mN/m, the deviation value comparing to the standard value is at 1.081mN/m.

Conclusions

This experiment presented the relations of electrical capacitance values of parallel conductive plates with 3 different diameters at the surface tension of 64.47mN/m – 72.75mN/m. At the water level of 98ml, when measuring the capacitance by LCR meter, the measurement results gave the difference of capacitance values in direct proportion to sizes of the parallel conductive plates and surface tension values of water. Having been calculated from the measured electrical capacitance values, the surface tension was at a good value comparing to standard value. The experimental results showed that the invented parallel conductive plates' structure were uncomplicated, inexpensive and can be invented by using printed circuit boards (PCB), and can be effectively used for measuring other kinds of liquids. The experimental results also explained that there is a possibility of development of the measurement of surface tension, by using this technique, inside a lab or for industrial work.

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