Application of Electrical Conductivity Measurement Techniques for Drinking Water Filling Process

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Abstract. *This research project proposed the design of the drinking water filling process with respect to control the amount of distributed water in accordance with the setting levels by using electrical conductivity measurement technique. The conductivity detection system was tested by attaching the end of the filling head with a stainless-steel rod with a diameter of 0.2 mm and two different levels of depth. The pitches of the stainless lars were adjusted to be 0.5, 1.0, 1.5, 2.0 and 2.5 centimeters. In addition, the pneumatic systems were used in the filling system of the filling heads. It was found from the experimental test-rig that the optimum length of the two stainless-steel bars were 2.0 centimeters with only slightly error of 0.5%; where the error was dependent on the amount of water pressure. The designed technique could help to reduce maximum 1% of excessive amount of water loss during the filling process.*

1. Introduction

At present, the production of drinking water for sale is increasing, and the size of containers range from a bottle of 350 cc, 600 cc, and 750 cc to 20 liters. To fill up the water, workers turn on the water tap and let the water in. The water level in the containers is controlled manually. This manual process may result in the inconstant, low precision in the levels of water, or water overflowing; especially, in the case that worker has low skills, this could lead to the inability to increase production capacity and consequently cause high cost loss for the company, which is not preferable for investment.

Previous studies on the processes of automatic drinking water filling systems have been reviewed. It was found that the most often used method is the pressure method. The method utilizes the water pressure to control the water level on top of the bottle. In this method, the water stops automatically when reaches the desired setting level. The problem found from employing this method is that the pressure may cause the bottle to break, and the production cost is high. This study proposes the alternative way to fill up the water by using the conductivity measurement method to avoid forcing pressure on the bottle which will reduce the chance for wreckage.

The research methodology of the present study started from measuring the amount of drinking water from the top of the bottle, using the principle of conductivity measurement. After that, the signal from the measurement was then sent to the input of the programable logic control (PLC) to process the work order to act as a water output device or to stop the water when the amount of water is full. Then, the different sensor levels that control the overflow levels or fill up full bottles were tested and compared by using stainless steel rods as the conductors for measuring conductivity. It is noted that four-terminal conductivity cells could be used rather than conventional two- terminal sensors due to their relatively less in sensitivity errors that might be caused by varying impedance of the electrode blood interface [5],[7]. However, in this research, the two-terminal sensors were used to meet because two-terminal catheter-based designs have used stainless steel rod electrodes.

In order to understand how the measurement technique works, the mathematical analysis on impedance of the relevant parameters. It is noted that the imaginary inductance is a part of complex inductance and can be deduced from the impedance definition as follows [1]:

$$Z/j\omega = R_z/j\omega + L_z = Im(L) + Re(L) = L \qquad (1)$$

When:

$$Z = R_z + j\omega L_z \qquad (2)$$

And

$$L = Z/j\omega = (R_Z + j\omega L_Z)/j\omega = Im\,(L) + Re\,(L) \qquad (3)$$

; where Z is the water impedance, ω is the angular frequency, and L is inductance appearing in the water.

Therefore, the aim of this work is to study the technique for facilitating the drinking water filling process. The parameters under consideration in this research are the distance away from the electrode, water pressure and energy on drinking water filling process.

2. Material and Method

2.1 Water Heat Design

The designed electrode sensor head consists of 3 stainless steel rods. To measure water level that can adjust the distance of the stainless-steel tip, the rods were placed on the water container as shown in in Fig. 1. The position of each sensor head can be adjusted to achieve less level than the tip of the water head that the water could be fed into the drinking water bottle.
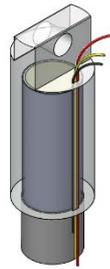
(a)
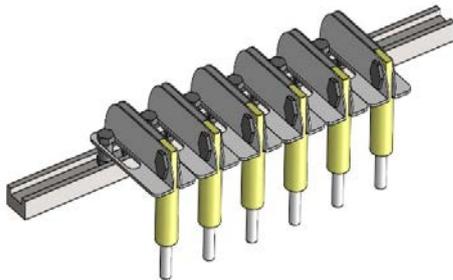
(b)

Fig. 1: Structure of designed water heating head: (a) photograph of the sensor head rod and (b) installation position of the sensors

2.2 System operation control

To control the operation of water supply of the filling head, the conductivity of drinking water was measured and the signals were sent to the input of Programmable Logic Controller (PLC). The data was then processed according to the program designed to control the solenoid valve of the water supply. When filling, the conductivity of the water in the water bottle must be measured.

When the set point for full amount of water was reached, the water supply must be immediately stopped. The control of the amount of drinking water in the bottle were adjusted in 2 ways, namely: x and y distances. As shown in Fig. 2, the sensor heads of the three stainless steel bars were attached in the filling head and the ends were connected with electrical wires that do not have water. At least 16 inputs and 12 outputs from the Programmable Logic Control (PLC) were used, receiving signals from sensors and commanding the solenoid valves to work according to desired programmed conditions.

Fig. 2: Conductivity control module of drinking water filler head

2.3 Experimentation

When the amount of water reaches the position at full, the conductivity was measured by adjusting the x and y distances to stop filling the water. If the correct spacing was adjusted, both values will cause the volume to stop at the desired position. Therefore, it is necessary to find the appropriate distance by adjusting the distances at the range of 0.5, 1.0, 1.5, 2.0 and 2.5 centimeters as shown in Fig. 3.

When the distance of the suitable bare stainless-steel bars was adjusted, the water pressure was adjusted to reduce or increase the water pressure at between 50-100 %. This could be done by increasing the adjustment 10 % step by step to see the amount of water being cut. The experimental test-rig are shown in Fig. 4.
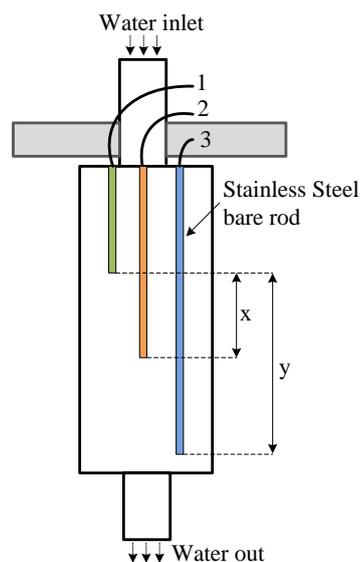

Fig. 3: A diagram of the conductivity sensor at the water filling head under this research work

Fig. 4: The experimental test-rig and setup

From the installation of bare stainless-steel bars, the conductivity measurement of the drinking water at the filling head had the values as follows:

x is the distance between points 1 and 2 in millimeters.

y is the distance between points 1 and 3 in millimeters.

3. Results and Discussion

2.1 Adjusting the electrode distances

In the first stage, the water pressure was adjusted at the valve position to reach the water distribution rate of 100 %. The distance of the stainless-steel shell electrode was gradually adjusted to two distance points: x and y. Table 1 shows the measurement of the conductivity at various distances.

x distance (cm)	y distance (cm)	Water Overflow (cc.)	Status of water in a bottle
0	0	600	x
0.5	0.5	80	/
1	1	100	/
1.5	1.5	120	/
2	2	120	/
2.5	2.5	140	/

Note: x= not working or overflow

Table 1 Experiment data of adjusted the electrode rods

Table 1 shows that the position of the electrode was adjusted at the distance equal to the reference axis. This stopped the conducting measurement and affected the control of water distribution. When continued increasing the distance, there was larger amount of water overflowing the bottle. Due to different conductivity measurements, there was an error in the detection system.

The next step is to adjust the fixed distance x and y, ranging from 0.5 to 2.5, and increasing each step by 0.5 cm. This helped to inform the applicable distance of the two electrodes to be used for water filling process (see Fig. 5).
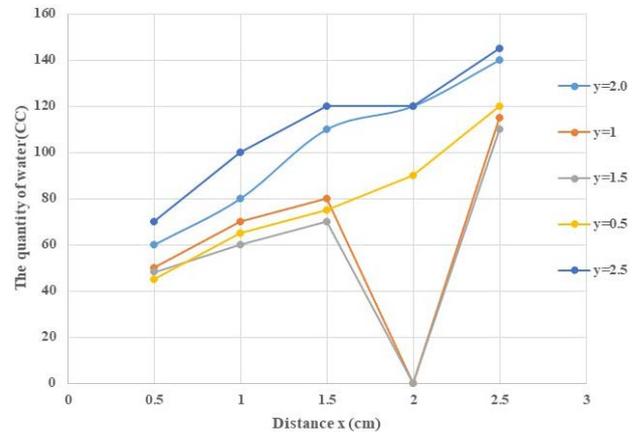

Fig. 5: Experimental results: water level error as a function of electrode distance.

Fig. 5 shows the loss of water and the distance of each electrode rod. After adjusting the distance between the two bars, the values of x were 1 cm. and 1.5 cm., while the value of y was 2 cm. These adjustments allowed the conductivity measurement to be able to stop the water supply according to the desired level. As for other spacing, errors varied. This shows that the adjustment of the distance of the electrode will allow to determine the water level.

3.2 Energy used in filling up water

Two sets Maple Logic Controller Program were used per each filling head to set the control of the drinking water filling system. The power supply was used for converting AC power into direct electricity. This helped to provide more security in the system. In addition, a 24-volt direct voltage of input and output was used to set up PLC circuit. The indispensable part was the air supply for lifting the filling up and down system when the amount of water was full. A 1.5 HP and 220 V reciprocating air compressor was used, and it was found that the working current was 0.78 A only while the work cycle of the air pump was at 8 minutes. The re-start of the air pressure depended on the size of the wind storage tank, and the appropriate air pressure was at 4 bars only. Meanwhile, the required energy for filling up 1 pack of water or 12 bottles is 0.05 kW per hour.

4. Conclusions

Adjusting the pitch of each bare rod at different levels will result in the discontinuation of water supply, where the distance between the x and y points is equal to 2 cm. and the distance x should be within 1 cm. from the reference point in order to enable the water level to stop at the specified position.

If the *x* and *y* distances was adjusted less or greater than the specified distance, it would cause the water to overflow immediately, and waste more water. However, the water pressure had few effects because the water levels rose quickly. This also helped to measure electricity charges and process orders to stop filling water.

The results from the experiment showed that the guidelines for measuring the conductivity of water for filling up drinking can be used with fragile bottles and help to reduce the amount of raw material loss. The water pressure is adjustable at any stage i.e. from the beginning of the valve opening up to the degree of one hundred percent.

Acknowledgement

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Biography

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