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Fluid Volume Detector on a Horizontal Tube Using an Ultrasonic-based Water Level Sensor

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***Abstract*—Measurement of the volume of liquid in a vertical cylinder can be done by multiplying the area of the circle with the length of the cylinder. Likewise, measuring the volume of liquid in a horizontal pipe can also be done by multiplying the area by the length of the cylinder. There is a difference between the two measurements of the volume of liquid in the cylinder. In a horizontal cylinder, the measurement of area used is a measurement of the segment of the circle that is exposed to the liquid. To get the value of the circle area segment that is with geometric analysis. In this study, in measuring the volume of liquid in a horizontal cylinder using the multiplication between the circle area segment and the horizontal pipe length. The variables used in measuring the volume of liquid in a horizontal cylinder are, cylinder diameter 2r, liquid level H, and cylinder length L. So that in making this measuring instrument the volume of liquid in a horizontal cylinder has two variables, namely fixed and variable variables. free. For the fixed variables, namely the diameter and length of the cylinder, and for the independent variables, namely the level of the liquid level in the H pipe. In measuring the independent variables, a proximity sensor Type HC-SR04 is used. Installation of a volume measuring device on a horizontal cylinder using a PVC pipe connection type equal tee which is connected to other pipes with the same diameter with a predetermined total length. The fixed variable that has been determined is the cylinder diameter of 10.16 cm with a length of 100 cm. Calibration was carried out in two stages, the first was calibration of the measurement of the liquid level between the HC-SR04 as the y variable against the WP150B calipers as the x variable, with a measurement range from 0 to 100mm, so that the equation y = (1.0003x - 0.023) mm was obtained. The second calibration was carried out to ensure the volume value of the tool readings that had been made using the HC-SR04 sensor as the y variable, against the Beaker Glass Pyrex calibrator with a capacity of 5000 mL as the x variable, so that the equation for the calibration results y = (1.0035x - 105.18) mm. The calibration results are linear line equations, so that the manufacture of a liquid volume measuring instrument in a horizontal pipe using an ultrasonic sensor can be implemented.**

Keywords—cylinder, liquid, ultrasonic sensor, volume

I. INTRODUCTION

Measurement of cylinder volume in a vertical position can be obtained by calculating the area of the circle times the height of the cylinder. Similarly, for the volume of a horizontal cylinder, the equation for the volume of a vertical cylinder also applies when the cylinder is completely filled. However, measuring the volume of a cylinder in a vertical position cannot be used to measure the volume of a cylinder in a horizontal position when the material or substance does not fill the full space of the cylinder. Measurement of volume in horizontal conditions certainly requires a different way from measuring the volume of the tube in a vertical position [1, 2].

Measurement of volume on a horizontal tube is very necessary, especially for measuring liquids that are in pipelines, for example in sewer pipes. The volume of liquid flowing in the drain pipe does not completely fill the pipe[1].

Antonio Valiente Barderas, et.al (2016) has performed calculations for the volume of cylinders filled with liquid in both vertical cylinders and horizontal cylinders. In horizontal cylinders to measure the volume of liquid in a cylinder covered with a plate, it is influenced by the height of the liquid that occupies the cylinder and the diameter of the cylinder and the length of the cylinder. So in calculating the volume of liquid that fills a horizontal cylinder with geometric analytical calculation techniques, namely by calculating the area of the segment filled with liquid multiplied by the length of the cylinder [1, 3].

In this study, the aim is to calculate the volume of liquid in a horizontal pipe, so that the geometric analytical method can be applied by cutting the pipe to a certain length.

II. Theoretical Background

A. Volume liquid on a pipeline

The volume of the pipe in the horizontal state can be considered as a horizontal tube [1, 3]. A cylinder has a variable length and radius either vertically or horizontally. If depicted a horizontal tube as shown below.

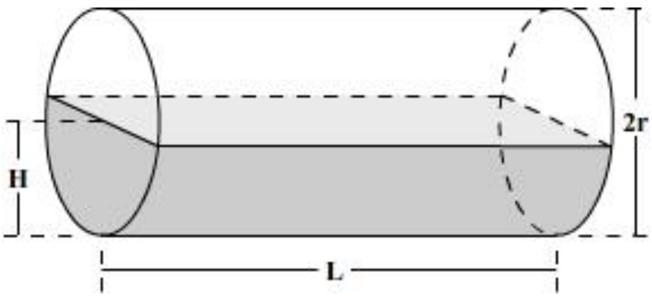

Figure 1. Tube filled with liquid

From Figure 1 above, a horizontal tube with a diameter of 2r is filled with liquid as high as H from the bottom of the horizontal cylinder. The part of the tube filled with liquid is called the horizontal cylindrical segment.

To calculate the volume of a cylinder filled with liquid, it can be multiplied by the area of the circle segment filled with liquid and the length of the cylinder [1,3]. In writing the equation to determine the volume of a cylinder filled with liquid is as follows.

$$V(L,r,H) = L\left[r^2 \cos^{-1}\left(\frac{r-H}{r}\right) - (r-H)\sqrt{2rH - H^2}\right]$$

The above equation is obtained from the geometric analytical calculation method, namely by finding the segment of the circle area or the segment of the horizontal cylinder multiplied by the length of the cylinder. The area segment of a circle is a fluid-filled circular plane oriented parallel to the axis of symmetry of the cylinder [3]. Where the circular area segment of a cylinder filled with liquid is formulated as follows.

$$A(r,H) = \left[r^2 \cos^{-1}\left(\frac{r-H}{r}\right) - (r-H)\sqrt{2rH - H^2}\right]$$

The variable r is the radius of the circle, and H is the height of the liquid filling the cylinder.

B. Ultrasonic Sensor

Ultrasonic sensor is a sensor module that can be used to measure the distance of an object without having to make contact between the object and the sensor [4]. The working principle of the ultrasonic sensor in its use to measure the distance of an object is by measuring the length of time it takes to send and receive ultrasonic sound waves that are reflected from the medium whose distance is being measured [4, 5].

Ultrasonic Sensor type HC-SR04 can be used to measure distance by combining it with a microcontroller via digital pins on the microcontroller, and the microcontroller can display the distance measurement results on the LCD [6,7,8,9,10].

III. System Overview And Experimental System

In this study, the system architecture in the form of hardware will be divided into two parts, namely, the first electronic system architecture in the form of wiring sensors, amplifiers, microcontrollers, and displays. Both system architectures are hardware level measuring sensors HC-SR04 on the pipeline.

A. Architecture for data fluid level

The hardware installation in this study consisted of an HC-SR04 sensor, NodeMCU ESP8266, and an OLED Display as shown in Figure 2.

From Figure 2, the HC-SR04 sensor which is a sensor that can measure the height of the liquid level in a pipe, the HC-SR04 in measuring the level of the liquid by means of the transmitter part of the sensor, which transmits ultrasonic signals to the surface of the liquid, which then from the surface of the liquid will reflect back the ultrasonic signal to the sensor on the receiver. In the HC-SR04 module section, the ultrasonic signal time between the transmission and receiver will be detected which is then processed by the microcontroller as the distance or level of the liquid level. The height value as the liquid level will be processed into the volume of liquid in the pipe by entering the height variable in the horizontal cylinder volume formula. The value of the height or liquid level and the value of the volume of liquid in the cylinder will be displayed to the display in the form of an OLED LCD so that it can be observed[9], and the second is sent via a wireless network to the server via ESP8266 as data recording in the form of the level or height of the liquid and the volume of the liquid that fills the cylindrical horizontal.

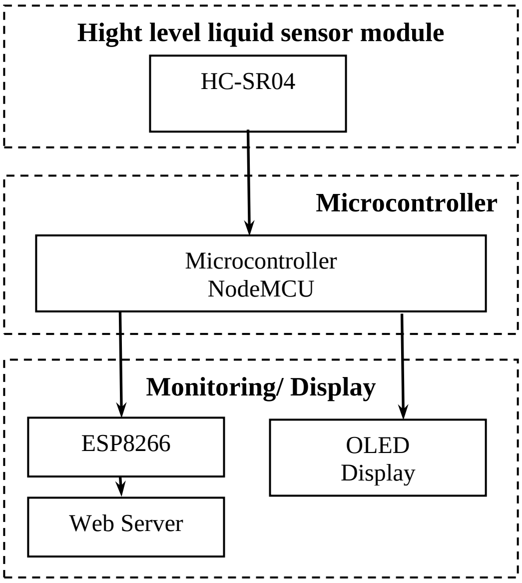

Figure. 2. Fluid level measurement system architecture.

In the architecture of the liquid volume measurement system in the horizontal pipe from Figure 2, it can be described a wiring system to connect each hardware so that it becomes a complete liquid volume measurement system in the horizontal pipe. Here's the wiring system.

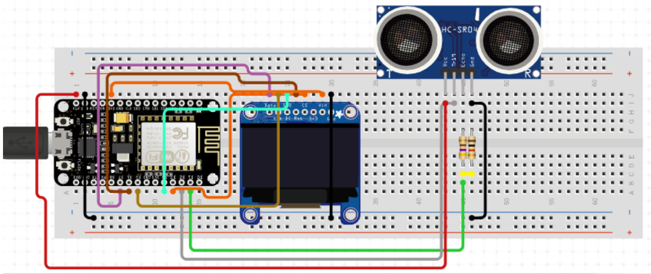

Figure. 3. Wiring hardware in fluid level sensor instrumentation

In Figure 3, each module is the HC-SR04 liquid level sensor module, NodeMCU microcontroller module, OLED module as a display, all of the wiring is connected to an external power supply with a potential difference of 5 volts DC. The HC-SR04 module gets its power supply from the input voltage on the NodeMCU ESP8266, then the output of the HC-SR04 is wired to the NodeMCU digital pin as a microcontroller. The wiring output from the microcontroller is connected to the OLED module which functions as a display. Meanwhile, as a data recording to a web server, it is sent via a wireless network via the ESP8266 module.

B. Sensor level architecture in pipelines

To implement the measurement of the volume of the liquid in the horizontal pipe by using the HC-SR04 sensor as a level or liquid level gauge in a conceptual design as shown in the image below.

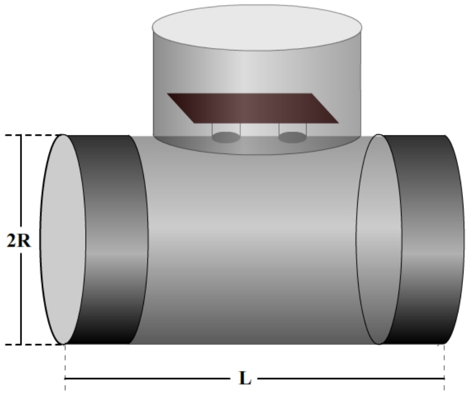

Figure. 4. Design fluid level on the pipeline

In Figure 4, the liquid level sensor is placed on an equal tee type pipe connection, to facilitate installation in the piping network. A proximity sensor or liquid level height sensor HC-SR04 is placed on the PVC pipe connection type equal tee which has a diameter of 10.16cm. Installation of HCSR04 and NodeMCU on the pipe connection is shown in Figure 5 below.

Figure. 5. Implementation HC-SR04 sensor on PVC pipeline connection

In Figure 5, the sensor that functions to measure the height of the liquid level, namely the HC-SR04 is connected hardware to a microcontroller. In measuring the liquid level in the pipe, the transmitter and receiver of the HC-SR04 are right at the top of the pipe. The reading of the liquid level in the pipe will continue to be read by the HC-SR04 sensor which will then be obtained by the NodeMCU microcontroller as the volume of the liquid in the pipe.

IV. Experimental Result

In ensuring that the reading of the height value on the sensor that has been made has met the altitude measurement standards. The first step that must be done is to calibrate the HC-SR04 sensor which has been made with a standardized length measuring instrument, namely the WP150B digital caliper. Then measure the volume of the sensor readings, calibrate with a Pyrex Glass Beaker with a capacity of 5000 mL.

Before calibrating the level of the liquid level and the volume of the liquid in the pipe, all components are installed correctly first. The overall length of the pipe is 100 cm with a pipe diameter of 10.16 cm.

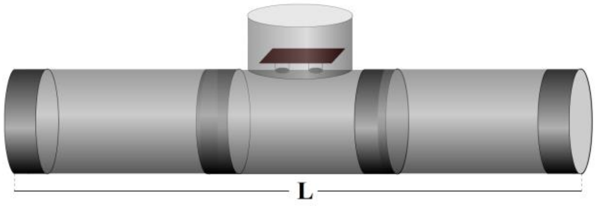

Figure. 6. Installation of fluid level and volume calibration

Calibration between the HC-SR04 sensor and a ruler is carried out to ensure that the readings of the HC-SR04 sensor are in accordance with their values with the WP150B calipers. The way to calibrate these two tools is by using a flat plate that can be shifted up and down as a substitute for the liquid surface.

From the results of the calibration of the HC-SR04 sensor with a ruler carried out in the pipe, the calibration data obtained between the HC-SR04 with a ruler as a calibrator is presented in the following graphic form.

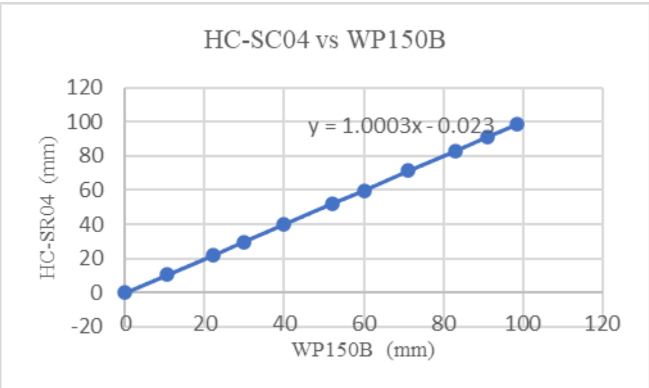

Figure. 7. Graph HC-SR04 versus WP105B.

From the graph in Figure 7, the calibration is carried out from 0 mm to 100mm.

So that the linear equation above is used as an equation on the microcontroller to measure the level of the liquid level.

The second stage of calibration is to calibrate the sensor readings by including the volume equation on the horizontal pipe to the Pyrex Glass Beaker with a capacity of 5 liters.

The way to calibrate the liquid volume is by measuring the volume of water in a 5 liter Pyrex Breaker Glass measuring glass, the Pyrex Glass readings are recorded, then the water is poured into a horizontal pipe so that it is read by the height level sensor that has been made.

The results of the volume calibration obtained by the HC-SR04 sensor readings against the Glass Pyrex readings are as follows.

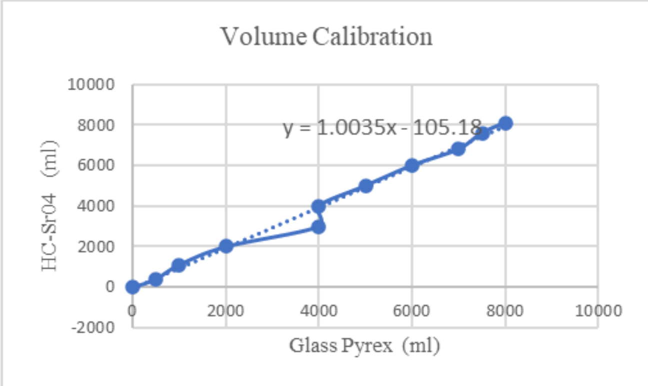

Figure. 8. Graph of equipment volume calibration against glass pyrex

From the graph in Figure 8, the results of the liquid volume sensor readings in the horizontal pipe form a linear equation, so that the tool that has been made can be applied as a measuring instrument for the volume of liquid in the horizontal pipe.

V. Conclusions And Research Suggestions

From the results of the implementation of the distance sensor HC-SR04 as a measuring instrument for the level of the liquid level used to measure the volume of liquid in a horizontal pipe using the equation for the area of a circle segment multiplied by the length of the pipe, it can be implemented as a measuring instrument for the volume of liquid in a horizontal pipe.

The difference in volume measurement between Glass Pyrex readings and the sensor that has been made is caused by the scale reading on Glass Pyrex and the presence of droplets when pouring water from Glass Pyrex into the pipe.

The suggestion to do next is try to do calibration using a digital volume measuring cup. For volume formulations on horizontal pipes it is also necessary to try again with other formulations.

For further development, it is necessary to measure the level of the liquid level with the HC-SR04 sensor to measure the flow rate of the liquid using the flow velocity sensor.

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