DESIGN OF DENSITY AND DENSITY CALCULATOR AS A BASIC PHYSICS EXPERIMENT TOOL

Ahmad Radhy[1*], Wildan Irsa Nugraha [1]

[1] Departement of Instrumentation Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia. E-mail: ahmadradhy@its.ac.id

Email of corresponding: ahmadradhy@its.ac.id

Present Address:
Gedung A Kampus ITS, Keputih, Kec. Sukolilo, Surabaya, Jawa Timur 60117, Indonesia

Abstract—One of the characteristics of liquid fluid is that it has a density. Many research methods have been carried out on this case, therefore in this study a simple method of measuring density was developed accompanied by a specific gravity connected via PC. The prototype consists of a loadcell sensor with the HX711 module which can convert the change in strain or resistance into a form of tension, a *flow* sensor is used to measure the volume of a liquid fluid through the *input* debit of liquid fluid *flow* in the measuring cup, and a mini pump equipped with a high and low relay mode with a voltage of 12 volts. The object of this study uses 3 types of fluids namely water, sugar water, and salt water. Measurement experiments were carried out by injecting the liquid by turning on the pump using the start button on the interface and pressing the stop button when it reaches the desired setpoint. Data from the volume of the liquid is obtained then compared with the results of density and specific gravity measurements theoretically. From the results of calculations and data analysis of 3 liquid fluids using static characteristics, the error value is 4,14% for water, 11,25% for sugar solution, dan 23,5% for salt solution.

Keywords— Flow, Leakage, Loadcell, density, HX711.

1. INTRODUCTION

Density is a parameter for measuring the mass of an object with its volume (Budhi Rahardja & Ilmar Ramadhan, 2019), while specific gravity is the result of multiplying the density by the gravitational force. The greater the density of an object, the greater the mass to volume of the object (Islamuddin & Soedarmadji, 2020). The amount of density (density) is used to determine the density of an object (Hariska et al., 2019) while the specific gravity is used to describe the state of a substance that has been compared with a standard (usually water) (Suwadji & Pebriana, 2018). Substances can be in the form of solid, liquid and gas (Dina Shofia, 2021). These three substances have different characteristics, solids tend not to change shape easily and have a fixed volume (Ariyansah et al., 2020), liquids have a fixed volume but their shape follows the container (W. Sari, 2020), while gases have volume and irregular shape and tends to follow the container (Kristoyono & Gunarti, 2018). The application used in industry is the density (Prasetyo, 2018) and specific gravity (Syahrial, 2019) used to determine the quality of a material. While the application to academics, the density and specific gravity are used for learning. The root of the problem that the author wants to raise is found in the conditions that exist in the field because there has not yet been found a counter for density and density due to the absence of measuring instruments that make it easier for them to identify and analyze the amount of mass to volume so that density calculations are still done manually. From these problems the author wants to propose the title of making the prototype for design and build for experiment.

2. METHOD

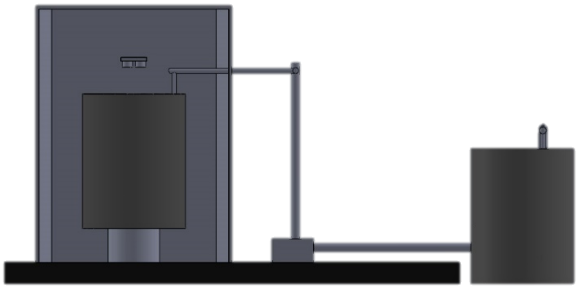

Figure 1. Three-dimensional design components

The three-dimensional design of this study shows some equipment, including the water tank above the ground and other components on the table. On the table there are hose, pumps, relays, sensors, and boxes. The fluid flow starts from the water tank as an inlet to the miniplant with a tank volume of 1L. The water in the tank will be pumped using a 1-inch hose to the check relay to prevent back pressure which can damage the pump. Water that passes through the check relay will pass through the ball relay to reduce water flow so that it does not fill the hose too quickly. Then the water will go through a reducer which will reduce the hose from 1 inch to half an inch which has been installed with a pressure sensor and a flow sensor. The water that has been measured by the pressure sensor and the first flow sensor. Solenoid relay for regulating flow and pressure so that it matches the set point or has a pressure of ±10 psi when the water is compressed or the relay is closed. The flow rate set point is the difference in flow rate at the first and second sensors, the difference is due to a leak. The difference in flow rate on the first and second sensors is 20%. To find out the pressure and flow of water has reached the set point by placing a pressure sensor and flow sensor after the solenoid relay. Controlling the pressure and flow rate using the microcontroller in the panel box. The panel box contains an Arduino Mega microcontroller, I2C LCD and electrical wiring. The water that is regulated according to this research will go through a branching hose in which there is a different relay in the hose. Placing different relays in the form of globe relays and ball relays aims to compare the performance in holding pressure and regulating the water flow. The performance of the two relays is evidenced by two sensors after the relay, the pressure sensor and the flow rate sensor. Water from branching hoses installed by different relays will be mixed together and go to the water tank.

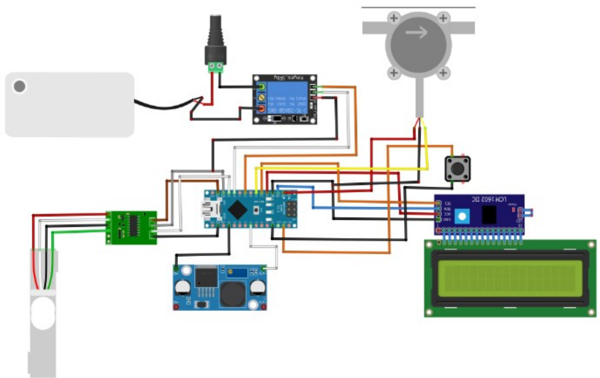

Figure 2. Electrical wiring design

A detailed explanation of the electrical wiring system can be seen in Figure 2. Figure 2 explains that all components except the solenoid relay use 5V DC voltage. The solenoid relay uses a 12V DC voltage. The pressure sensor has an analog output signal so that it is connected to the microcontroller analog pin. The flow rate sensor has a digital output signal so that it is connected to the microcontroller digital interrupt pin. The 20x4 I2C LCD uses a digital signal on the output signal so that it is connected to a special pin for the lcd, namely SDA and SCL microcontrollers. The buzzer is mounted on the digital pin. The relay is connected to the digital pin and the solenoid relay is connected to the relay pin at COM and ground from the power supply. The control block diagram starts from the input of the physical quantity of pressure and flow rate through consideration or error correction which means that there is a measurement variable setting. Physical quantities (inputs) will be controlled using the Arduino Mega microcontroller which will be used in this study. The microcontroller gets the value of the electrical quantity to make error correction from the pressure and flow

rate sensor. Sensors convert physical quantities into electrical quantities. The microcontroller will send a command signal in the form of an electric quantity to the actuator on the PDAM miniplant in the form of a solenoid relay. The output is the pressure and flow rate according to the setpoint.
The set point of the flow rate parameter is the calculation of the water loss up to 20%. If it is less than 20%, then the solenoid relay is fully open. While more than 20%, the solenoid relay becomes full close. The pressure parameter set point is a pressure of 10 psi. If it is more than 10 psi, then the solenoid relay is fully closed. While the pressure is less than 10 psi the solenoid relay is fully open. Each parameter and leak status will be sent a signal to the display in the form of a 20x4 I2C LCD as a Graphic User Interface (GUI) so that it can be seen by observers.

3. RESULT AND DISCUSSION

3.1. Sensor Test Results

3.1.1. Loadcell Sensor Validation

Tool testing is carried out to see the level of accuracy of the prototype that has been built. Submissions are made by comparing measuring instruments with digital scales using a variety of samples, namely water, cooking oil, oil, 70% alcohol, coconut oil, liquid oxygen, glycerol, mercury, acetic acid, benzene, shampoo, sea water, pure milk. , hands sanitizer, pertalite, spiritus, blood, syrup, honey, and Pertamax Turbo. The mass-to-strain value obtained comes from the load generated by the load cell and digital scales with a mass range of 100 grams to 600 grams.
The test was carried out three times with seven times data collection. There are four pressure sensors located before the solenoid relay, after the solenoid relay and the leak point, after the ball relay, and after the globe relay. The pressure sensor readings listed are the average of three repetitions.

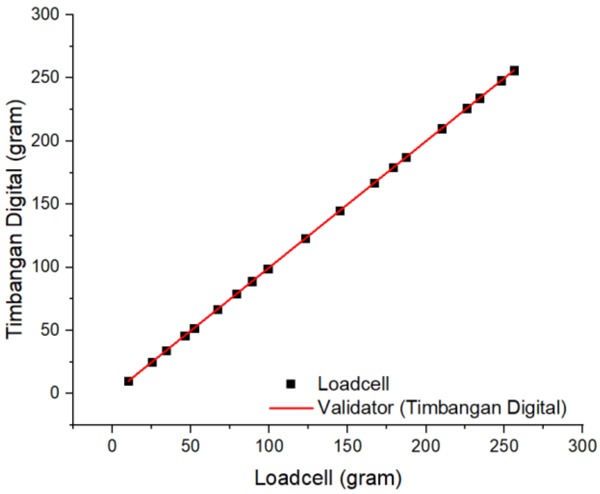

Figure 3. Loadcell sensor validation chart

Based on Figure 3, it can be seen that the loadcell sensor an average accuracy of 100% and an average inaccuracy value of 0%. The inaccuracy of the pressure sensor is still below the limit of the inaccuracy value in the datasheet of 5%, so that the loadcell sensor is still considered valid.

3.1.2. YF-S401 Flow Rate Sensor Validation

Flow rate sensor test to validate volume measurement results with measurement glass as a comparison validator so that sensor accuracy is obtained [12]. The test is carried out by pumping water in the tank into a glass that has a volume indicator installed and a validator as the tool being tested.
The test was carried out three times and data were collected twenty times. The sensor and validator readings listed are the average of three repetitions.

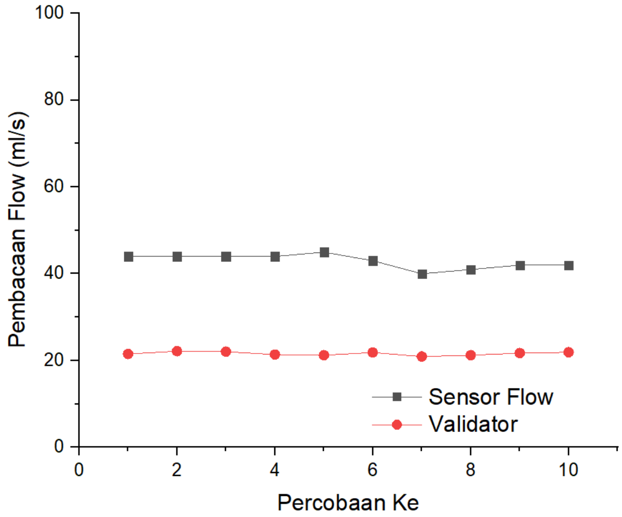

Figure 4. flow rate sensor validation chart, before solenoid relay

Based on Figure 4, it can be seen that the flow rate sensor before the solenoid relay has an average accuracy of 34,74% and an average inaccuracy value of 73,88%. The inaccuracy of the flow rate sensor is still below the limit of the inaccuracy value in the datasheet of 5%, so that the flow rate sensor is still considered a invalid.

3.2. Performance System Test

Tool testing is carried out to see the level of accuracy of the prototype that has been built. The test was carried out by comparing the results of the calculation of the measuring instrument prototype with theoretical comparisons using uses 3 types of fluids namely water, sugar water, and salt water. The process of testing the tool is carried out by placing a load cell under a measuring cup to calculate the mass of liquid then a flow sensor is used to measure the volume of liquid whose output has been determined by the relay to activate the mini pump, if the interface on the computer is pressed start then the relay will be active, if the computer is pressed stop then the relay will turn off and if the keyboard is pressed reset then the tool will reset to 0. The prototype performance test was carried out 10 times with different volume variations and calculated the time needed for the liquid to fill the measuring cup using a stopwatch.

Table 1. System test response to meassure density of water

No	Condition	ρ (density)		ɣ (specific gravity)		Control Response	Ratio (%)
		Measurement	Referencee	Measurement	Referencee		
1	No-leak	0,0	0,0	0,0	0,0	Normal	0,0
2	No-leak	12,0	12,0	18,8	0,0	Normal	0,0
3	No-leak	12,0	12,0	19,0	4,5	Normal	0,0
4	No-leak	11,0	11,0	17,2	5,4	Normal	0,0
5	No-leak	11,0	11,0	16,4	6,5	Normal	0,0
6	No-leak	11,0	11,0	21,4	11,3	Normal	0,0
7	No-leak	10,0	10,0	21,4	15,3	Normal	0,0
8	No-leak	9,5	9,5	21,8	10,6	Normal	0,0
9	No-leak	2,3	2,3	22,9	9,1	Normal	0,0
10	No-leak	0,0	0,0	23,9	9,3	Normal	0,0
11	Leak	12,0	11,0	17,9	0,0	Normal	8,3
12	Leak	12,0	10,0	15,0	0,0	Normal	16,7
13	Leak	12,0	9,0	16,0	0,0	Normal	25,0
14	Leak	8,0	5,8	31,0	0,0	Normal	27,5
15	Leak	1,2	0,4	32,0	0,0	Normal	66,7
16	Leak	0,0	0,0	30,0	0,0	Normal	0,0

Table 2. System test response to specific gravity of water

No	Condition	ρ (density)		ɣ (specific gravity)		Control Response	Ratio (%)
		Measurement	Referencee	Measurement	Referencee		
1	No-leak	0,0	0,0	0,0	0,0	Normal	0,0
2	No-leak	12,0	12,0	18,8	0,0	Normal	0,0
3	No-leak	12,0	12,0	19,0	4,5	Normal	0,0
4	No-leak	11,0	11,0	17,2	5,4	Normal	0,0
5	No-leak	11,0	11,0	16,4	6,5	Normal	0,0
6	No-leak	11,0	11,0	21,4	11,3	Normal	0,0
7	No-leak	10,0	10,0	21,4	15,3	Normal	0,0
8	No-leak	9,5	9,5	21,8	10,6	Normal	0,0
9	No-leak	2,3	2,3	22,9	9,1	Normal	0,0
10	No-leak	0,0	0,0	23,9	9,3	Normal	0,0
11	Leak	12,0	11,0	17,9	0,0	Normal	8,3
12	Leak	12,0	10,0	15,0	0,0	Normal	16,7
13	Leak	12,0	9,0	16,0	0,0	Normal	25,0
14	Leak	8,0	5,8	31,0	0,0	Normal	27,5
15	Leak	1,2	0,4	32,0	0,0	Normal	66,7
16	Leak	0,0	0,0	30,0	0,0	Normal	0,0

From the data in Table 1, it can be seen that the measurement of density works according to the on/off in controlling mode, even though there is an excess of pressure and returns to the setpoint. From data numbers one to sixteen, the density can be change because the amount of the volume is changed. From the data in Table 2, it can be seen that the measurement of specific gravity works according to the on/off in controlling mode, even though there is an excess of pressure and returns to the setpoint. From data numbers one to sixteen, the density can be changed because the amount of the density is changed.

4. Conclusion

The A prototype for calculating density and specific gravity has been made as a means of basic physics experiment. The prototype of calculating density and density has been analyzed as a means of basic physics practicum using flow sensors and load cell sensors.
Of the 3 liquid fluids namely water, sugar water, and brine using the load cell sensor and flow sensor used for the trials, the average density and density errors were 4.17% for water, 11.25% for salt water, and 23.3% for sugar water. However, this prototype is still limited to research so there are still deficiencies in the mechanics.

CREDIT

Conceptualization, Methodology, Writing - original draft preparation, and Supervision: Ahmad Radhy; Formal analysis and investigation: Ahmad Radhy, Wildan Irsa Nugraha ; Writing - review and editing: Ahmad Radhy, Wildan Irsa Nugraha; Funding acquisition: Ahmad Radhy, Wildan Irsa Nugraha; Resources: Ahmad Radhy, Wildan Irsa Nugraha.

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