

IoT Based Glass Bottled Water Production System at Raden Rahmat Mosque

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Abstract—Raden Rahmat Mosque manages an independent drinking water production unit for the congregation and social needs. Previously, this facility had not used a packaging machine (cup sealer) and only relied on bottle packaging. The use of bottles creates production costs that reach Rp850 per bottle, much higher than glass packaging which is around Rp180 per glass. In addition, the lack of real-time production data reporting makes it difficult for those in charge to monitor. Therefore, this study aims to design and build an automatic cup sealer machine based on the Internet of Things (IoT). The Design and Construction method is implemented using an ESP32 microcontroller integrated with an infrared sensor to detect the number of production cups, a stepper motor actuator, and a web platform for remote monitoring and authorization. The results of system performance testing show an average error rate of 5.21 percent for the 120 milliliter target water volume and 2.94 percent for the 180 milliliter target, with a packaging landing success rate of 90 percent for the 180 ml size and 80 percent for the 120 ml size. In telecommunications testing, the success rate of telemetry data transmission to the database reached 99.5 percent, accompanied by a wireless operational approval percentage of 100 percent.

Keywords: Cup Sealer, ESP32, Motor Stepper, Sensor Infrared, Water Flow Sensor, Web

I. INTRODUCTION

Providing independent drinking water at socio-religious institutions like the Raden Rahmat Mosque plays a crucial role in supporting the operational efficiency of public facilities. Currently, drinking water needs are met using bottled water, which requires a production cost of Rp 850 per unit. This high cost index drives the need for a functional transition to the use of glass containers, which only require a production cost of Rp 180 per unit. This packaging shift can physically reduce operational costs by more than 70 percent, thus optimizing financial efficiency for social activities.

However, the main obstacle in producing glass packaging independently lies not only in the higher cost of bottle packaging, but also in the monitoring aspect because the lack of real-time production data reporting makes it difficult for those responsible to supervise. Although several previous studies have implemented automation systems on packaging machines, most of these innovations are still standalone. The limitations of these conventional instruments include the lack of a telemetry system to monitor the accumulation of production quantities in real time, as well as weak remote authorization control to prevent system malfunctions in the field.

This research aims to address this technological gap by designing and building an automatic cup sealer machine system integrated with the Internet of Things (IoT) ecosystem.

Using an ESP32 microcontroller as the data processing center, this system is designed to automate the entire production cycle, from cup lowering via a stepper motor, water volume filling based on a water flow sensor, to the packaging thermal sealing process. In addition to the mechanical automation aspect, this research focuses on the implementation of a two-way communication architecture via a wireless network. This protocol allows the Person in Charge to monitor daily production quantities and provide operational authorization remotely via a website interface to maintain the security of the tool's instrumentation.

II. METHOD

This research uses a design and construction method that includes the design and construction of hardware architecture, software, and integration of Internet of Things (IoT)-based telemetry systems.

A. System Overview

The automation system for this cup sealer machine is based on several basic concepts of instrumentation and information systems. The ESP32 microcontroller is used as the main control center because it has superior computing capabilities and the integration of a built-in Wi-Fi module that is very adequate to

facilitate Internet of Things (IoT) communication [1]. Precise liquid flow measurement relies on a water flow sensor that works based on the Hall effect principle, where the rotor rotation due to liquid flow is converted into a series of electrical pulses that can be calculated by the microcontroller [2]. Meanwhile, the main mechanical movement is controlled by a stepper motor. This motor offers a high level of positional precision through discrete step control without requiring a complex closed-loop feedback system [3]. Transmission of production data and authorization commands is realized through a web telemetry architecture using the HTTP protocol and a MySQL database, which allows for asynchronous remote monitoring execution [4].

B. Hardware Architecture

The hardware architecture of this automatic cup sealer machine design is comprehensively represented through a system block diagram. This block diagram serves as a fundamental reference that describes the physical configuration, electrical topology, and functional interconnection relationships between components that make up the entire electronic subsystem of the Internet of Things (IoT)-based packaging machine. Through this schematic representation approach, the complexity of the tool design is systematically and structured into four main hierarchies, namely the input block (sensor data acquisition system), the process block (central data processing unit), the output block (mechanical actuation system), and the server block (telemetry data communication infrastructure). The functional interconnection relationships of all these components are visually shown in Figure 1.

Input module functions as data input. This component includes an ultrasonic sensor to detect the availability of empty glasses in the dispenser, Ultrasonic sensors work based on mechanical wave propagation. The use of this ultrasonic sensor is often combined with output components as a sensor reader media including LED lights, buzzers, to LCD modules [5]. Water flow sensor to measure water flow pulses, Water flow sensors are sensors that function to calculate water discharge, the speed of flowing water, and the amount of water that has flowed in milliliters or liters depending on the units entered in the program [2]. Water level sensors to monitor water capacity in gallons, in this system using the XKC-Y25-NPN Sensor. Three limit switches as determinants of the zero reference point (homing) of motor coordinates, limit switches are used to limit the work of a tool that is operating. NC, NO, and central terminals can be used to disconnect the flow of electricity in a circuit or vice versa [6]. As well as push buttons as discrete interrupt providers to select the target volume, push buttons are electronic components that can disconnect and flow electric current in an Arduino project circuit. Where this disconnection and flow occurs due to the principle of switching from one conductor to another. This is done by direct manual operation by the user [7].

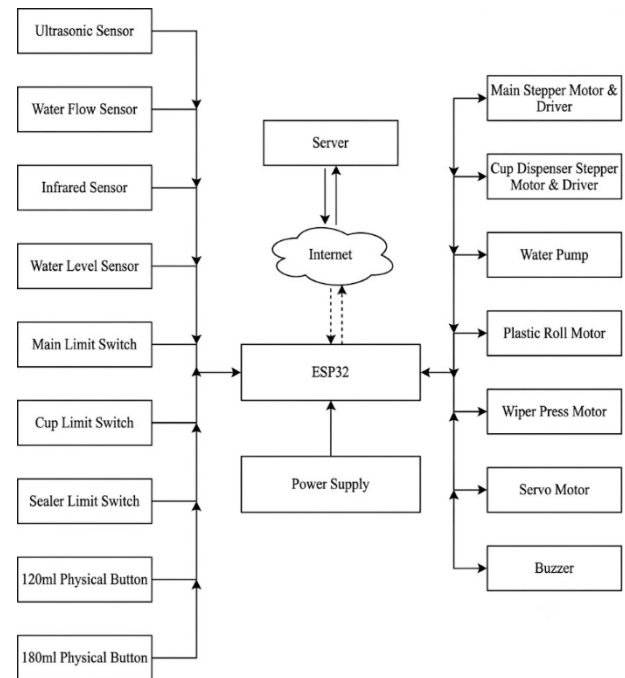


Figure 1. System Block Diagram

Processing module using the ESP32 microcontroller as the Central Processing Unit (CPU). The ESP32 is responsible for acquiring input signals, executing programs from the ESP32, generating Pulse Width Modulation (PWM) signals, and managing the internal (on-board) Wi-Fi module communication for data transmission. The ESP32 is a microcontroller developed by Espressif Systems, providing a powerful and affordable platform for building IoT applications. The Tensilica Xtensa LX6 dual-core microprocessor on this platform offers higher processing power and efficient multitasking [1].

Output module consists of actuators that execute physical movements. The main component is a NEMA 23 stepper motor controlled by a TB6600 driver as the main conveyor drive, Nema-23 is a type of variable reluctance stepper motor that rotates due to the rotor teeth being attracted by the stator poles due to the magnetic attraction that moves when electric current flows through it [8]. While the TB6600 Driver is a motor driver used to control stepper motors, especially bipolar stepper motors. This driver can regulate the current flow and activation pattern of the stepper motor coils, making it possible to control the position, speed, and direction of motor movement with precision [9]. A 12 VDC water pump motor is used to pump and take water from a gallon to be distributed to a glass through a hose medium, a water pump is a series of machines used to move water from its source to the desired place [10]. Plastic heater actuator (wiper) driven by wiper dynamo via BTS7960 driver, BTS7960 motor driver is an electronic component that functions as a controller for high current DC motor. It is included in the H-bridge motor driver category, which allows control of the direction of motor rotation and regulates its speed [11]. Plastic scrap roller relay, how it works is when an electric current is connected, contact

will occur between the plates so that an electric current can flow. In other words, the relay is an indirect switch that is controlled using a current source [12]. As well as a servo motor to lift the glass to the ejector, the control of the MG996R servo motor rotation angle is controlled directly by the ESP32 microcontroller via Pulse Width Modulation (PWM) signal transmission. MG996R receives a 50Hz frequency PWM signal [13].

C. IoT Software and Integration

Software development is divided into two instruments, namely firmware on ESP32 (using C/C++), PHP-based web and database using MySQL. MySQL is a database program management based on data with basic commands from SQL that can send and receive data at high speed and can be used by many users and many flows [14]. In website creation there is a flowchart of website usage. The flowchart of website usage is a visual representation of the interface logic flow (dashboard) used by users to monitor and control the cup sealer machine.

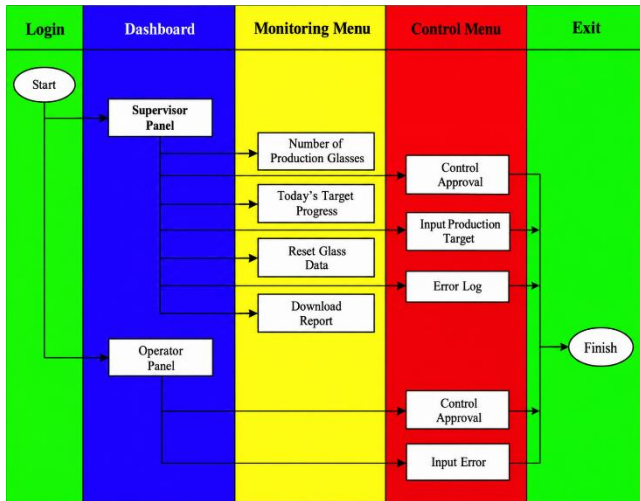


Figure 2. Website Usage Flowchart Diagram

Based on Figure 2, this flowchart differentiates functional access based on user roles, namely between Responsible Person and Operator, to ensure operational governance runs according to authority. Meanwhile, the ESP32 firmware is programmed using the Arduino IDE software to ensure the machine operates according to the predetermined work sequence. Data exchange between the machine and the server is implemented via the HTTP (Hypertext Transfer Protocol) protocol.

D. How The System Works

This sub-chapter presents a main flowchart that comprehensively summarizes the entire system process, starting from initial initialization, water volume selection, sealing process, until the completion of one production cycle. Based on Figure 3, the system work cycle begins with the network initialization stage. The person in charge selects the target quantity and size to be produced, the operator receives a production request from the person in charge via the website,

after which the operator presses one of the push buttons on the machine, when the operator presses the push button to select the target volume, the machine will evaluate the operating mode (Online/Offline).

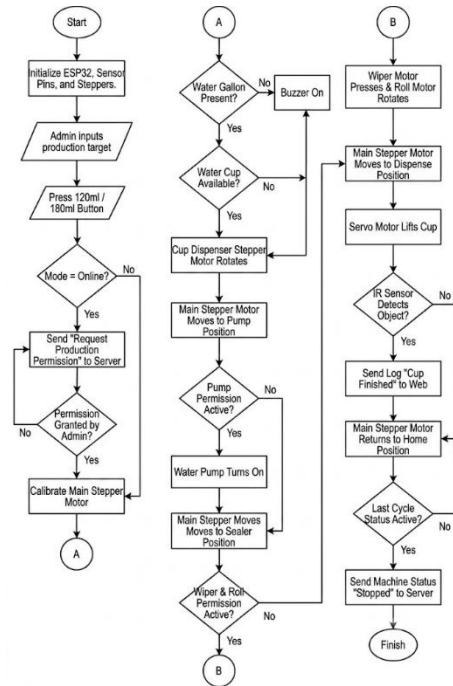


Figure 3. System Flowchart

In Online mode, the ESP32 sends authorization request parameters to the server and waits for approval (True status) from the Responsible Person via the web interface. Once authorization is granted, the system calibrates the stepper motor to the homing coordinates. The cycle continues by detecting the presence of water in the gallon and checking for the presence of a glass in the dispenser. If valid, the conveyor moves to the water filling point where the pump is automatically activated until the water flow sensor reaches the setpoint (120 ml or 180 ml). Next, the conveyor moves to the sealer point for thermal pressing, followed by movement to the ejector point to eject the packed glass. When the infrared sensor at the exit position detects a glass falling, the ESP32 sends completion data to the database to update production statistics in real-time.

III. RESULTS AND DISCUSSION

The performance evaluation and validation of this Internet of Things (IoT)-based automatic cup sealer machine system was conducted through five isolated functional testing stages and one integrated system check stage. This approach aims to comprehensively analyze mechanical precision, instrumentation accuracy, and data communication protocol reliability.

3.1 Water Volume Accuracy Testing

This test focuses on the performance of a filling subsystem that integrates a Hall-effect-based water flow sensor with an ESP32

microcontroller and a 12 VDC water pump drive relay module. Fluid dosage stability is a key variable in ensuring consistent product quality.

The purpose of the water volume accuracy test is to validate the level of accuracy and precision of the digital data reading of the water flow sensor in measuring the liquid flow volume and its ability to automatically stop the pump flow at the target parameters (setpoint) of 120 ml and 180 ml.

Testing was conducted 20 times for each target volume variant. Water distributed through the nozzle was collected into a glass and its mass was measured directly using a high-precision digital analytical balance (assuming the density conversion of pure water $\rho = 1 \text{ g/ml}$). The difference between the actual volume from the weighing and the target volume was calculated to obtain the error rate.

TABLE I
WATER VOLUME ACCURACY TEST RESULTS

Experiment To-	Target Volume (ml)	Actual Volume (ml)	Difference (ml)	% Error
1.	120	89	31	25,83%
2.	120	115	5	4,17%
3.	120	114	6	5,00%
4.	120	113	7	5,83%
5.	120	116	4	3,33%
6.	120	113	7	5,83%
7.	120	117	3	2,50%
8.	120	115	5	4,17%
9.	120	116	4	3,33%
10.	120	115	5	4,17%
11.	120	116	4	3,33%
12.	120	115	5	4,17%
13.	120	116	4	3,33%
14.	120	114	6	5,00%
15.	120	114	6	5,00%
16.	120	115	5	4,17%
17.	120	116	4	3,33%
18.	120	114	6	5,00%
19.	120	116	4	3,33%
20.	120	116	4	3,33%
21.	180	146	34	18,89%
22.	180	173	7	3,89%
23.	180	174	6	3,33%
24.	180	177	3	1,67%
25.	180	178	2	1,11%
26.	180	178	2	1,11%
27.	180	176	4	2,22%

Experiment To-	Target Volume (ml)	Actual Volume (ml)	Difference (ml)	% Error
28.	180	175	5	2,78%
29.	180	174	6	3,33%
30.	180	175	5	2,78%
31.	180	175	5	2,78%
32.	180	178	2	1,11%
33.	180	176	4	2,22%
34.	180	175	5	2,78%
35.	180	178	2	1,11%
36.	180	177	3	1,67%
37.	180	176	4	2,22%
38.	180	177	3	1,67%
39.	180	178	2	1,11%
40.	180	178	2	1,11%
Rata-rata	120	113,75	6,25	5,21%
Rata-rata	180	174,7	5,3	2,94%

Water volume accuracy testing was conducted, and the complete data of the test results are presented in Table I. Furthermore, Figure 4 illustrates the documentation of the water volume accuracy test that has been carried out. The results of the test measurements show that the system recorded an average error rate of 5.21% on the target volume of 120 ml (with an average actual volume of 113.75 ml) and 2.94% on the target volume of 180 ml (with an average actual volume of 174.7 ml).



Figure 4. Water Volume Accuracy Test Documentation

The deviation of the actual volume from the target setpoint is analyzed from the phenomena of hydrodynamics and electrical mechanics. Hydrodynamics is the science that studies flowing fluids. Fluids are flowing substances, consisting of liquids and gases. There are fluids that do not flow and there are fluids that flow. The science that studies fluids that do not flow is called hydrostatics and the science that studies fluids that flow is called hydrodynamics [15]. The observed error percentage is attributable to the inertia of the pump rotor, when the ESP32 microcontroller sends a cut-off signal to the relay module upon reaching the required sensor pulse count, the DC pump motor rotor does not stop spinning instantly. Instead, it undergoes a deceleration phase caused by mechanical inertial momentum and residual hydrostatic pressure or the dripping effect, whereby a column of liquid remaining in the distribution hose

between the shut-off valve and the nozzle tip leads to residual dripping due to gravity and static hydrostatic pressure immediately after the pump is turned off.

Although there is a volumetric deviation in the range of 2 to 7 ml, the average error rate is below the 6% range, confirming that the sensor pulse interrupt on the ESP32 operates well and is safe to use for public consumption on an MSME scale.

The most crucial initial stage in the operational cycle of an automatic cup sealer machine is the process of transferring empty cup material from the upper dispenser tube to the mounting hole on the main stepper track. Mechanical landing failure at this phase can stop the entire production sequence. Therefore, this test aims to measure and compare the percentage of success rate of empty cup dropping precision from the dispenser tube to the mounting hole of the main stepper motor in two cup size variants, namely 120 ml and 180 ml. Figure 5 is documentation of the successful cup dropping test.



Figure 5. Documentation of Glass Drop Success Test

Figure 6 shows the results of the glass landing test on the conveyor stand. The landing success rate reached 90 percent for the 180 milliliter packaging, and 80 percent for the 120 milliliter packaging. The occurrence of mechanical landing errors on the 120 milliliter glass was caused by the radial clearance tolerance of 7 millimeters on the conveyor stand, as well as the reduction in gravitational pressure (downward force) which is directly proportional to the reduction in the stack of glasses on the pusher dispenser.

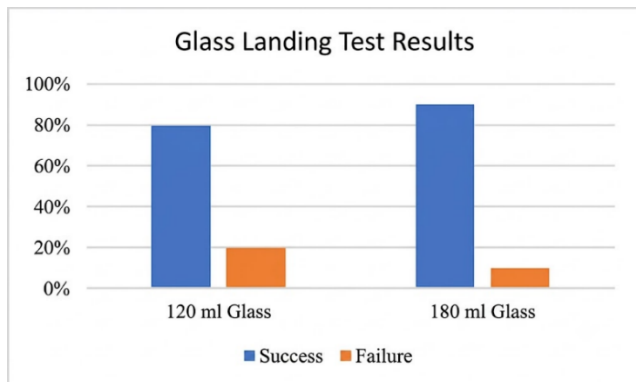


Figure 6. Glass Landing Test Results on Conveyor Mount

3.2 Accuracy Testing of Glass Count Monitoring

The telemetry subsystem is responsible for automatically monitoring the accumulation of production

results and transmitting counter data from the hardware to the server database via a wireless communication circuit.

The purpose of this test was to validate the reliability of the infrared sensor as an optical counter and to test the reliability of data packet transmission from the ESP32 microcontroller to the MySQL database via the HTTP protocol without data loss.

The machine was operated continuously, executing 400 consecutive production cycles, divided into four test groups (each of 100 cycles). The number of physical objects successfully lifted by the servo motor was manually verified and compared with the log entries recorded in the server database.

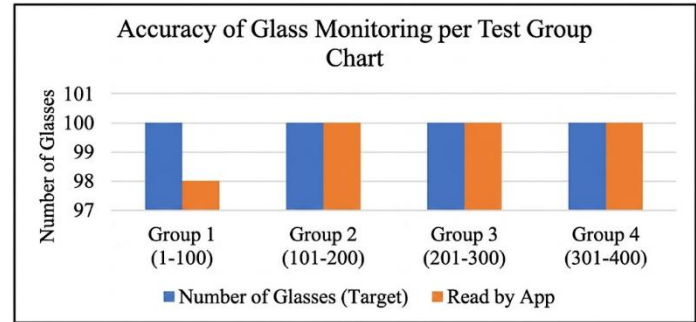


Figure 7. Glass Monitoring Accuracy Test Results

Figure 7 shows the results of the glass monitoring accuracy test. Out of a total of 400 continuous production cycles, the telemetry system successfully transmitted recording data accurately 398 times, with 2 recording failures identified at the beginning of the test (Trial 1 and 2). Quantitatively, this test resulted in a success rate of 99.5% and an error rate of 0.5%.

The observation results showed that the two detection failures in the initial cycle were purely caused by mechanical factors, namely the elevation angle of the infrared sensor which experienced a micro-shift due to vibration noise from the landing of the servo motor arm. After tightening the bracket mount and calibrating the optical sensor range, the data acquisition process ran stably without any lost data packets until the 400th cycle. Figure 8 is the documentation of the accuracy testing of the monitoring of the number of glasses that has been carried out.

3.3 Remote Authorization Activation Testing

The wireless authorization feature is a software-based security layer that limits access rights to hardware operations in the field through user hierarchy verification (role-based authorization) on the website interface.

The purpose of this test was to ensure that authorization instructions, including approval and rejection, from the control panel interface could be executed by the ESP32 microcontroller to control the machine's power circuit.

GLASS COUNT MONITORING REPORT		
Data retrieved on: 15-06-2026 20:38		
NO.	DETECTION TIME	TOTAL GLASSES
1	2026-05-22 15:19:14	398
2	2026-05-22 15:18:52	397
3	2026-05-22 15:18:30	396
4	2026-05-22 15:18:09	395
5	2026-05-22 15:17:48	394

Figure 8. Documentation of Accuracy Testing of Glass Count Monitoring

The tester acted as the person in charge and input authorization parameters into the web dashboard. The ESP32 sent repeated data calls (asynchronous polling) via the HTTP request protocol. The voltage response on the actuator's trigger pin was measured using a digital multimeter to verify the transition between logic states (0 VDC to 5 VDC).

In addition to monitoring, testing of the wireless control functionality (remote authorization) demonstrated a very optimal response.

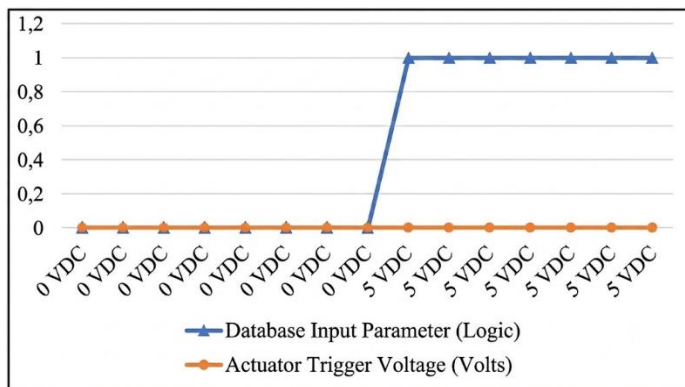


Figure 9. Machine Activation Success Test Results Based on Approval

Figure 9 shows the results of the Approval-Based Machine Activation Success Test. The machine activation and shutdown instructions sent via the web dashboard parameters were executed by the microcontroller without failure, with a 100 percent authorization execution success rate. This response reliability demonstrates that the implemented HTTP protocol architecture is capable of bridging the user interface with the hardware in real-time, minimizing the risk of operational malfunctions in the field.

3.4 Glass Sensor Detection Accuracy Testing and Mechanical Fault Tolerance

This testing phase focuses on evaluating the operational failure prevention system (fail-safe mechanism) integrated using the HC-SR04 Ultrasonic sensor instrument. In addition, this test also analyzes the level of precision of the mechanical movement of the stepper motor actuator in distributing the glass packaging containers from the dispenser tube to the

conveyor mounting hole. This protection system is crucially designed to prevent the fluid filling process without a container (dry-filling) which can cause damage to the machine's mechanical and electrical circuits.

The main objective of this integrated testing is to validate the accuracy level of the ESP32 microcontroller's decision-making logic based on spatial data feedback from the Ultrasonic sensor. Specifically, this testing measures the system's responsiveness in terminating the operational cycle (generating a Halt status) when the dispenser tube is detected as empty. In addition, this testing is also intended to quantitatively calculate the percentage of success in mechanically landing the glass into the conveyor hole in two different packaging dimension variants (120 ml and 180 ml).

Data collection at this testing stage is carried out systematically through a narrative sequence of operational procedures. First, the power to the cup sealer machine is initiated to ensure that the HC-SR04 Ultrasonic sensor interface is actively transmitting distance feedback to the microcontroller. Subsequently, 15 consecutive test cycles are conducted, which are classified into three parameter scenarios: 5 trials with the dispenser tube empty, 5 trials with the 180 ml cup filled, and 5 trials with the 120 ml cup filled. The process begins by issuing the initial execution instruction by pressing the physical switch (start button) on the machine's interface control panel. During the process, the logic status decisions of the ESP32 microcontroller are recorded, where logic 0 represents the machine lock instruction, and logic 1 represents the instruction to continue rotating the stepper motor. Next, direct visual observation is conducted to record the physical landing coordinates of the cups on the conveyor mounting matrix (categorized as "On Target" or "Stuck/Miss"), specifically in scenarios where the machine continues the operational process. Finally, the success rate and error rate are calculated using standard mathematics to comprehensively evaluate the system reliability.

The data collection results evaluating the fail-safe mechanism using the ultrasonic sensor are systematically tabulated in Table III. The overall percentage ratio of the detection and mechanical precision test is visually represented in Figure 10.

TABLE III
SENSOR DETECTION AND MECHANICAL PRECISION TEST RESULTS

Experiment To-	Target Glass Variant (ml)	Actual Ultrasonic Distance (cm)	ESP32 Execution Signals (Logic)	Mechanical Landing Status (Logic)
1	0	28.1	0	0
2	0	27.9	0	0
3	0	28	0	0
4	0	28.2	0	0
5	0	28	0	0
6	0	27.8	0	0
7	0	28.1	0	0

Experiment To-	Target Glass Variant (ml)	Actual Ultrasonic Distance (cm)	ESP32 Execution Signals (Logic)	Mechanical Landing Status (Logic)
8	0	28	0	0
9	0	27.9	0	0
10	0	28.1	0	0
11	120	6.1	1	1
12	120	6.3	1	1
13	120	6.2	1	0
14	120	6.1	1	0
15	120	6.4	1	1
16	120	6.2	1	1
17	120	6.3	1	0
18	120	6.1	1	0
19	120	6.2	1	1
20	120	6.1	1	1
21	180	5.2	1	1
22	180	5.3	1	1
23	180	5.2	1	1
24	180	5.1	1	1
25	180	5.4	1	1
26	180	5.2	1	1
27	180	5.3	1	1
28	180	5.2	1	1
29	180	5.5	1	1
30	180	5.1	1	1
Total	30 Percobaan	-	-	13,33%

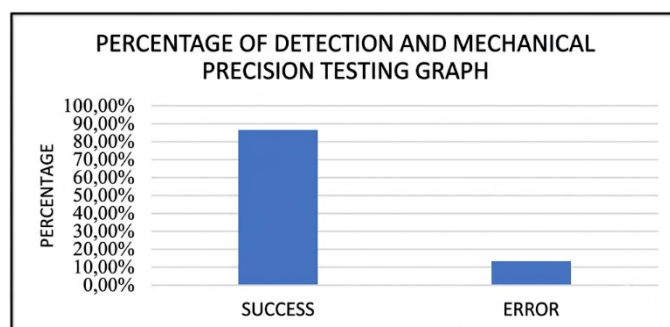


Figure 10. Mechanical Precision and Detection Test Percentage Graph

3.5 Glass Drop Success Test

The most crucial initial stage in the entire operational cycle of an automatic cup sealer is the transfer of empty cups from the upper dispenser tube to the mounting holes on the main stepper motor. Failure of the mechanical landing during this phase can cause malfunctions and halt the entire production sequence.

Therefore, this functional test aims to precisely measure and compare the percentage of successful cup drops from the dispenser tube to the mounting holes on the main stepper motor. This test compares two production package sizes: 120 ml and 180 ml cups.

The test procedure involves activating the machine to drop a stack of cups from the plunger dispenser. The landing of the objects is then observed to ensure that the cups fall precisely and accurately into the mounting holes on the conveyor. Data on the percentage of successful mechanical landings is presented in Table IV.

TABLE IV GLASS LANDING TEST RESULTS ON CONVEYOR MOUNT		
Experiment To-	120 ml Glass Variant	180 ml Glass Variant
1	Failed (Stuck)	Success
2	Success	Success
3	Success	Success
4	Success	Success
5	Success	Success
6	Success	Success
7	Success	Success
8	Success	Failed (Stuck)
9	Success	Success
10	Failed (Stuck)	Success
Success Percentage	80%	90%
Error Percentage	20%	10%

Based on the results of the glass landing test on the conveyor mount, the system demonstrated mechanical performance that was significantly influenced by the container's physical dimensions. The glass landing success rate reached 90 percent for the 180 milliliter packaging variant. Meanwhile, for the 120 milliliter packaging, the landing success rate decreased to 80 percent.

The decrease in success rate or the occurrence of mechanical errors when using 120-milliliter cups is due to the 7-millimeter radial clearance tolerance in the conveyor mount. This radial clearance error is further exacerbated by the reduction in downward gravitational force on the container. This reduction in gravitational force is directly proportional to the thinning of the cup stack in the dispenser.

To minimize errors in advanced operations, the dispenser's mechanical precision can be optimized by adding a passive component in the form of an anti-static coated guide ring/funnel to the bottom funnel. This modification aims to reduce the radial clearance tolerance, so that the center of gravity of the 120 ml glass can be directed to fall perfectly perpendicular to the holder.

IV. CONCLUSION

The automatic cup sealer machine system integrated with the Internet of Things (IoT) using the ESP32 microcontroller has been successfully designed, constructed, and implemented.

Based on system performance testing, the cup dropping mechanism achieved a 90% success rate for 180 ml containers and an 80% for 120 ml containers, with mechanical errors primarily caused by radial clearance tolerances. Furthermore, the telemetry subsystem successfully synchronized production data logs to the MySQL database with an accuracy of 99.5% across 400 cycles, while the remote authorization functionality demonstrated a 100% success rate. In the water filling accuracy test, the water flow sensor recorded an average error rate of 5.21% for the 120 ml target and 2.94% for the 180 ml target, confirming that the system operates with high precision and is reliable for automated production monitoring.

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