International Journal of Educational Technology Research (IJETR)
Vol. 2 No. 3, 2024 :419-434

Design of Automatic Control System in Filling Machine for Liquid Soy Sauce Based on Mitsubishi Plc And Hmi

Budi Artono[1]*, Basuki Winarno[2], Kumala Mahda H[3], Dimas Nur P[4],Wahyu Laksana Putra[5]

Politeknik Negeri Madiun

Corresponding Author: Budi Artono : *budiartono@pnm.ac.id*

A R T I C L E I N F O

Keywords: Filling Machine, PLC, HMI, Piston Pump, Pneumatic

Received : 20, July
Revised : 22, June
Accepted: 25, August

©2024 Artono, Winarno, Mahda H, Nur P, Putra(s): This is an open-access article distributed under the terms of the Creative Commons Atribusi 4.0 Internasional.

A B S T R A C T

A filling machine is a machine used to fill liquid products into packaging. This machineis an important component in the food and beverage processing industry, pharmaceuticals, cosmetics and other industries that require filling products into packaging quickly and efficiently. Based on general observations in the field, entrepreneurs in the field of packagingliquid product filling are still carried outconventionally with human labor in the filling process. So, in the end manually filling soy sauce products can cause a decrease in filling volume, consistency, speed and cleanliness which can affect the quality of the final product. In designing the control system for filling machines, three working modes are created, namely Manual Mode, Semi-Manual Mode and Automatic Mode. Manual and semi-manual work modes, the function is used if the automatic work system has an error or systemdamage, then the manual and semi-manual work mode functions will be activated. This HMIis also used as a control system for each machine working mode, and also for monitoring. Monitoring via HMI can be seen on the indicators of each component, making it easier to identify damage or errors in each component. In testing this filling machine, it is carried outby comparing the liquids to be filled, namely by using air and soy sauce into packaging bottles because there are differences in the viscosity of the liquids.

INTRODUCTION

A Filling *Machine* is a machine used to fill liquid products into packaging. This machine can be used in petrifying, packaging and filling various types of products. Products can be in the form of liquids, which are put into different types of packaging. Such as bottles, pouches, or cans. Based on observations in the field, entrepreneurs in the field of packaging and filling liquid products are still carried out conventionally with human labor in the filling process, such as opening/closing valves.

In addition, with the help of media such as funnels as a pouring medium. Thus, often the manual filling of soy sauce products can cause uncertainty in filling volume, consistency, speed and cleanliness which can affect the quality of the final product. One of them is to achieve this goal by implementing an automatic control system based on PLC and HMI. The engine system used in the filling process of this liquid product uses a piston pump system controlled by pneumatics. This is because the liquid used is soy sauce liquid or has a high density with a very thick liquid condition.

In line with that, the design of this tool aims to overcome these problems with "Design of Control System for Automatic Filling Machines for Soy Sauce Products Based on Mitsubishi PLC and HMI. Because of the reliability and technology of this PLC is able to control industrial processes, while HMI will provide interfaces and monitoring.

Problem Formulation

Based on the background that has been explained above, the questions that become the formulation of the problem arise. Which is formulated as follows:

1. How to design *the Wiring Diagram* and implement the installation system on the control panel *of the Filling Machine?*
2. How to design the control system on the *Soy Sauce Liquid Product Filling* Machine?
3. How to design the control and *monitoring* design on the HMI *filling machine*?
4. How to do the working test *of the Filling machine* for filling soy sauce liquid products?

Purpose

Based on the limitations of the problem, it can be explained that the objectives of the research/design of the final project are as follows:

1. Able to design *Wiring Diagrams* using *Q-Electro Software* and perform electrical system assembly on the engine control panel.
2. Able to design the control system of the *Filling* Machine using Mitsubishi PLC through *GX Works 2* software.
3. Can design control and *monitoring* systems using HMI "Weintex" through *Easy Builder Pro* software.

Able to test the work of *the Filling* Machine filling soy sauce liquid products through the test form.

METHODOLOGY

A. Component Planning

To make it easier to design a tool and so that the tool can run well, it is necessary to determine the specifications of the tool and the material, including the following:

1. PLC Mitsubishi
2. HMI Weintex
3. Power Supply 24VDC
4. Relay
5. Solenoid Pneumatic
6. Valve
7. Pneumatic
8. Sensor Proximity dan Sensor CS1-U
9. Kabel NYAF merah dan hitam 0.75 mm

B. System Schematics

The schema is made to make it easier to understand the working system of the tool to be created. Here is the working system of the tool to be created

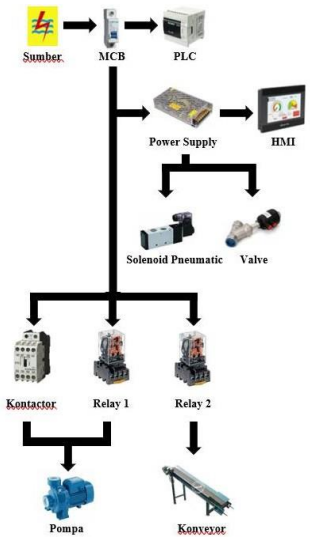


Figure 1. Tool-Wide System Schematic

C. *System Flowchart*

A flowchart is a workflow diagram of a tool or system that functions to facilitate a brief explanation of how a tool is created or used.

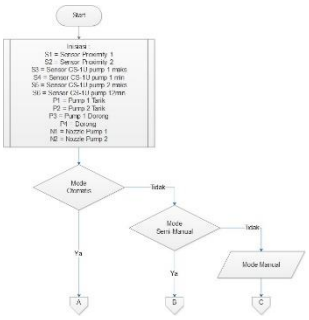


Figure 2. Flowchart System Working Mode Tool

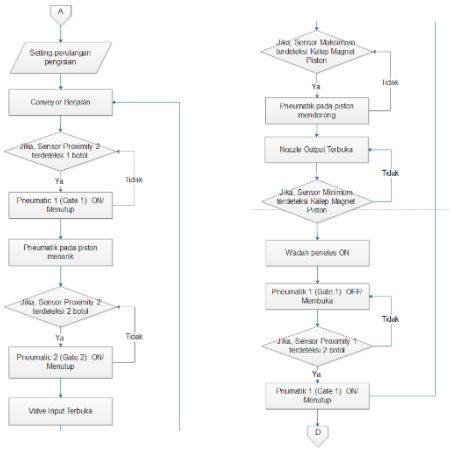


Figure 3. Otomatic Workflow System Flowchart

Figure 4. *Semi-Manual* Workflow System Flowchart

D. Hardware *Planning*

- Tool Planning

  In this section, planning will be discussed on the tools used for the implementation of the program.

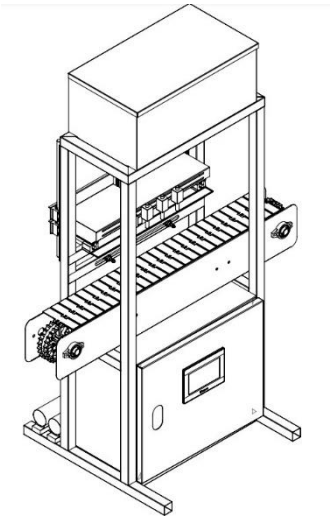


Figure 5. Tool Design

- Wiring Design for Mechanical Electrical Installation

  In the planning of the electrical installation, the engine control panel will be made in the Q-Electro Tech software, as follows:

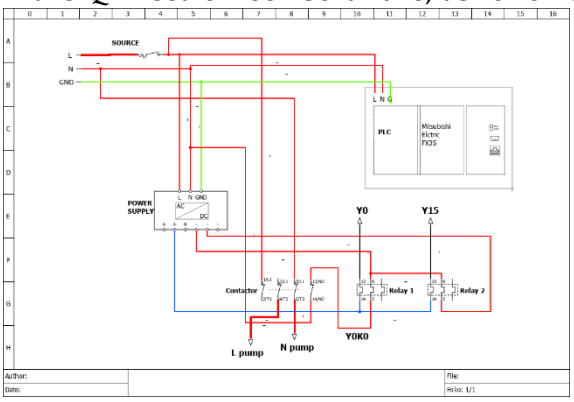


Figure 6. Power Wiring

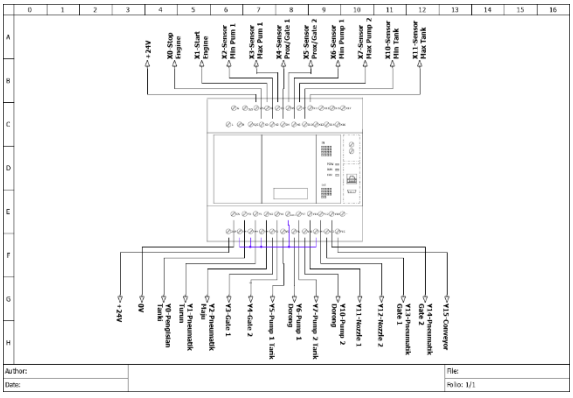


Figure 7. *PLC Wiring Input/Output*

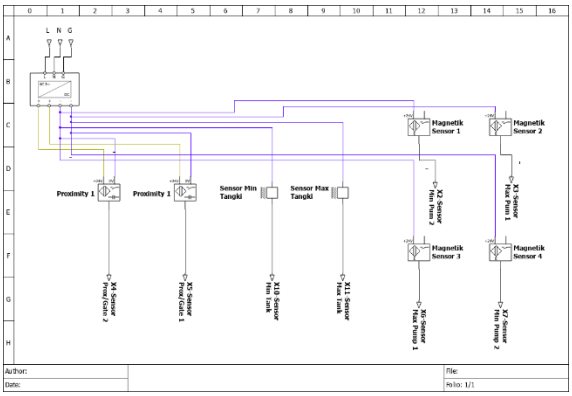
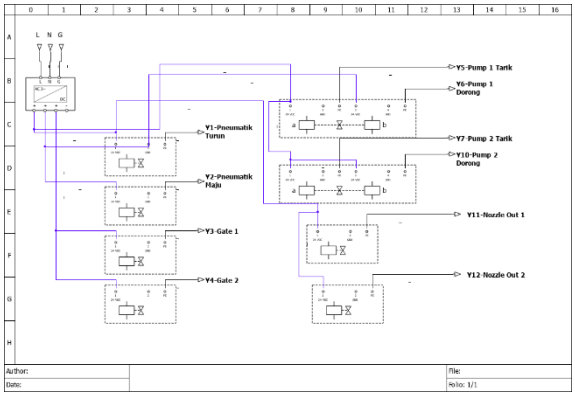


Figure 8. *Wiring Sensor*



Gambar 9. *Wiring Solenoid/Pneumatic*

- Assembly of Filling Machine Control Panel

The control panel of this machine has stainless stell material, which has dimensions of 60 cm in length, 35 cm in width and 50 cm in height,

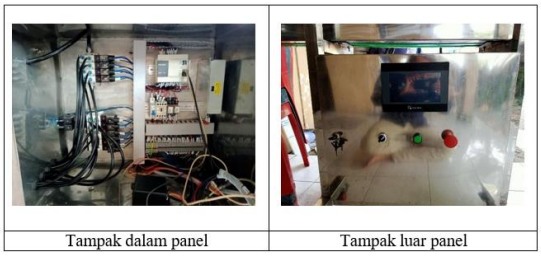


Figure 10. Control Panel Display

E. Software *Design*

- Program PLC Mitsubishi FX3U

This PLC program is made with the GX Works 2 application with LD (*Ladder Daiagram*) type. Below are parts of the Automatic work system program.

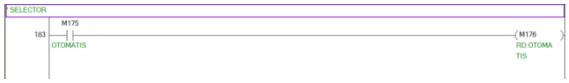


Figure 11. Automatic Selector

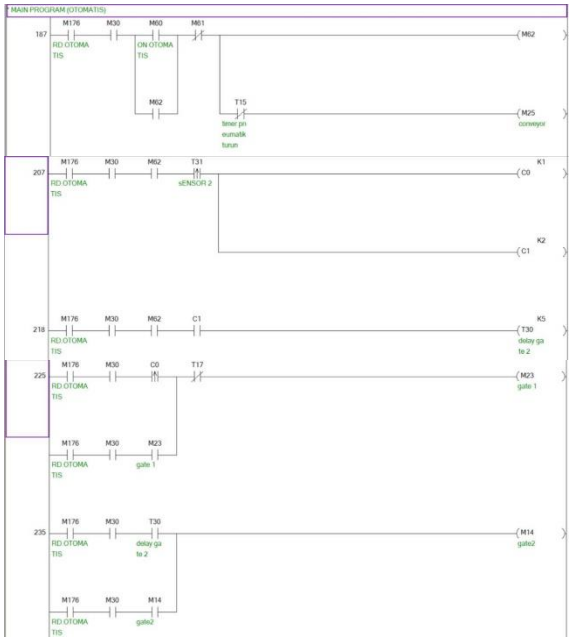


Figure 12. Counter sensor and Gate movement

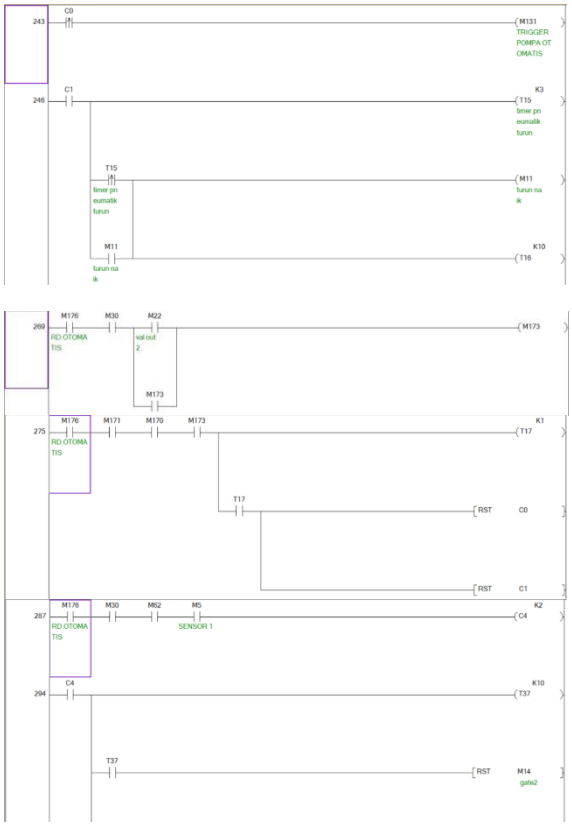


Figure 13. Charging Process

- HMI Design

This HMI is used to display and monitor the system. Design HMIs using *the Easy Builder Pro* app.

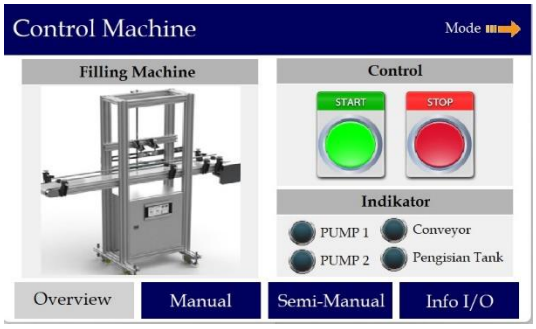


Figure 14. Design *Overview/Main control* HMI

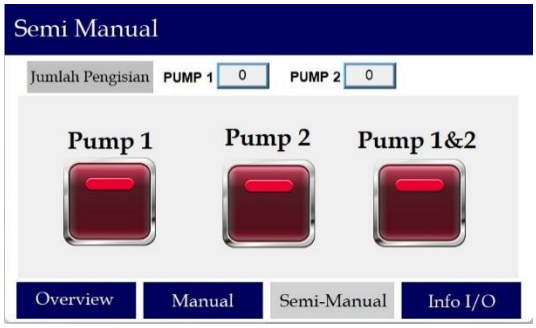


Figure 15. *Semi-Manual* Design HMI

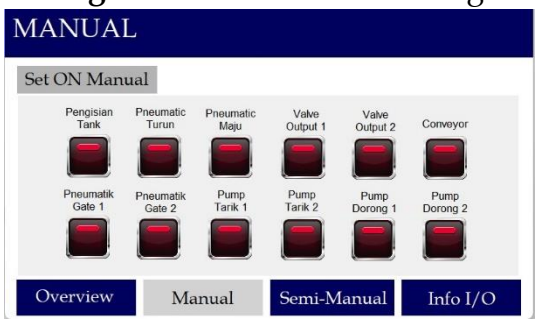


Figure 16. HMI *Manual Set On* Design

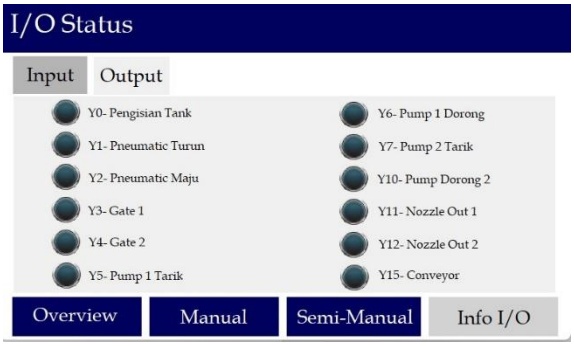


Figure 17. HMI Input/Output Monitoring Design

RESULTS AND DISCUSSION

At this stage of results and discussion, tests will be carried out on the tools that have been planned and made in advance to obtain data that will be discussed against the tests so that conclusions can be obtained so that this tool can be known in accordance with what was previously planned.

- **RESULT**

A. Tool Manufacturing

This part is the result of the design or physical shape of the *filling machine* that has been made.

Tampilan fisis mesin filling dari depan

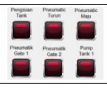
Tampilan fisis mesin filling dari belakang

Figure 18. *Physical Display of Filling Machine*

HMI Function

The following is an explanation of each function of the button in the HMI.

Table 1. Button Function and HMI Indicator

No	Gambar	Keterangan
1		Tombol *start/Stop system* untuk mengaktifkan mode kerja secaraotomatis mesin *filling*
2		Indikator sistem kerja otomatis, apabila dalam proses penarikan/ memompa cairan atau konveyor bekerja maka indikator akan menyala
3		Tombol *setting/selector* untuk memilih system kerja secara otomatisatau sistem kerja secara semi-manual
4		Tombol untuk mengatur perulangan proses pompa/tarikan piston beberapa kali menyesuaikan dengan kebutuhan
5		Tombol ON/OFF untuk penyalaan system kerja secara semi-manual (kerja pump 1 saja/ kerja pump 2 saja/pump 1 dan pump 2 secara bersamaan)
6		Tombol ON/OFF sistem kerja manual dengan menombol tiap actuator untuk melakukan kerja tiap actuator
7		Indikator pada input mesin *filling*, apabila suatu inputan mesin *filling* bekerja maka indikator akan menyala.

B. Hardware, Program and HMI Synchronization

In testing this manual work mode, it is carried out by combining each actuator that functions to ensure that each *actuator* can work according to its own function and the program can work properly.

1. Output Nozzle Testing 1 & 2

Table 2. Program Synchronization, HMI on Nozzle

Skenario Pengujian	Hasil Pengujian
Memberikan nilai 1 (ON) dengan menombol di HMI	**1. *Nozzle* out 1&2 sebelum bekerja** Katup *nozzle* dalam kondisi menutup  **2. *Nozzle* out 1&2 setelah bekerja** Katup *nozzle* dalam konsisi membuka  ***3.* Program *Ladder Diagram***  **4. *Monitoring* pada HMI** Pada *monitoring* HMI ini merupakan pemantauan output Y11&Y12, ketika output *Nozzle* aktif/ON, maka indikator Nozzle Y11&Y12 pada HMI akan menyala.  ***5. Solenoid*** *Solenoid Pneumatic* Y11&Y12 pada panel kontrol akan menyalakan indikator apabila *output Nozzle* aktif. 

2. Proximity Sensor Testing

This test is carried out by testing the proximity sensor distance. The photoelectric *seambor* is used as an automatic switch that works with *a variable* output to determine the distance converted into electricity.

Table 3. Tensile Test Measurements

No	Jarak Pembacaan Sensor	Indikator LED	V output
1.	5 cm	On	24,10 VDC
2	5cm	Off	0,624 VDC
3	10 cm	On	24,10 VDC
4	10 cm	Off	0,624 VDC
5	20 cm	On	24,10 VDC
6	20 cm	Off	0,624 VDC
7	30 cm	On	24,10 VDC
8	30 cm	Off	0,624 VDC

Picture 19. Tension Test Results with Avometer

3. Testing *Error Machine* & *Safety System*

This test is carried out when the condition of the machine is in *an error* condition in the production process or this system is used if the machine is in *an emergency condition,* this is used as a *safety system.*

Table 4. Program Synchronization and HMI *Safety System*

Skenario Pengujian	Hasil Pengujian
Dengan menombol *emergency stop* apabila terjadi proses produksi yang *error*	**1. Program *Ladder Diagram*** • Emergensi stop • Proses **2. *Monitoring* pada HMI** Pada *monitoring* HMI ini merupakan pemantauan apabila EMG bekerja maka *output* pompa dorong akan bekerja, maka indikator pompa dorong Y6&Y10 akan menyala. **3. *Solenoid*** *Solenoid Pneumatic* Y3&Y10 pada panel kontrol indikator akan menyala apabila output pompa dorong aktif.

C. Testing/Production

This process is a production test on *the filling* machine to find out the performance of the *filling machine* based on various parameters and operating systems. Here are the many variations and *setiing* on bottle filling.

1. Liquid Water

In the picture below is the result of the automatic water filling process into the bottle. Here are the results of automatic production.

Table 5. Results of Measuring Production on Water

Produksi	Hasil Produksi	Hasil Ukur Pompa 1	Hasil Ukur Pompa 2
Produksi Ke-1			
Produksi Ke-2			
Produksi Ke-3			
Produksi Ke-4			
Produksi Ke-5			
Produksi Ke-6			

Table 6. Analysis of production measurements on water

Produksi	Hasil Ukur Pompa 1 (ml)	Hasil Ukur Pompa 2 (ml)	Time (s)	Ukuran Sensor (cm)
Produksi Ke-1	285 ml	280 ml	9,86 s	8 cm
Produksi Ke-2	280 ml	280 ml	9,72 s	8 cm
Produksi Ke-3	285 ml	280 ml	9,53 s	8 cm
Produksi Ke-4	285 ml	285 ml	4,91 s	8 cm
Produksi Ke-5	285 ml	280 ml	4,80 s	8 cm
Produksi Ke-6	280 ml	285 ml	4,86 s	8 cm

2. Soy Sauce Liquid

In the picture below is the result of the automatic water filling process into the bottle. Here are the results of automatic production:

Tabel 7. Production results in soy sauce liquid

Produksi	Hasil Produksi
Produksi Ke-1	
Produksi Ke-2	
Produksi Ke-3	

Table 8 . Analysis of production measurement results in soy sauce liquid

Produksi	Hasil Ukur Pompa 1 (ml)	Hasil Ukur Pompa 2 (ml)	Time (s)	Ukuran Sensor (cm)
Produksi Ke-1	145 ml	145 ml	6,11 s	4 cm
Produksi Ke-2	148 ml	148 ml	6,06 s	4 cm
Produksi Ke-3	145 ml	145 ml	6,06 s	4 cm
Produksi Ke-4	140 ml	140 ml	5,31 s	4 cm
Produksi Ke-5	140 ml	140 ml	5,41 s	4 cm
Produksi Ke-6	175 ml	145 ml	5,55 s	4 cm

CONCLUSION

Based on the design and testing of the tool, the following conclusions can be drawn:

1. Wiring *diagram* design can be used by designing/conceptualizing using *Q-Electro software* and in the manufacture of the filling machine can be arranged or assembled the control components in the panel according to the specifications that have been determined and perform functional tests on all components to ensure that all components can operate correctly.

2. In designing the control system on the *filling machine,* it is made with three working modes, namely Manual Mode, Semi-Manual Mode and Automatic Mode. Manual and semi-manual working modes, the function is used if the automatic working system has *an error* or system damage, then the manual and semi-manual working mode functions will be functioned by regulating the filling on the pump (simultaneous pump work or pump 1 only/pump 2 only). In addition, in the filling process, this machine is also equipped with a *looping* systemfilling, which is where in the filling process we can adjust several filling processes according to the capacity or needs of the packaging bottle and also have a *safety machine* system that is used if the machine is *in an error* condition.

3. This filling *machine* is controlled with an interface through HMI (*Human Machine Interface) technology,* where in this HMI it is also used as a system control on each machine working mode, and also as *monitoring*. *Monitoring* through HMI can be seen on the indicators of each component, so that it can be easier to identify damage or errors in each component.

In testing this *filling machine*, it is carried out by comparing the liquid to be dispensed, namely by using water and soy sauce in a bottle, because there is a difference in the vicosity of the viscosity of the liquid. This can make it easier for researchers to make observations or improvements to the machine. For example, in the initial test there was a difference in filling time with the result of soy sauce liquid faster than soy sauce so that the researcher made a discussion, namely by changing several components such as the size of the valve diameter

From 2.5 cm to 5 cm due to the inhibition of liquid flow, the size of the piston pump will affect the contents of the size produced in one withdrawal or one pump, namely using the latest size with a width of 13 cm and a length of 23.5 cm

BIBLIOGRAPHY

Arid, I., Junaidi, J., & Yulfira, Y. (2022). *DESIGN OF FILLING UNIT ON A PLC-BASED AUTOMATIC BOTTLE FILLING MACHINE*. *3*(2), 33–34.

Firdiansyah, F., & Muliawati, F. (t.t.). *DESIGN AND BUILD AN AUTOMATIC TIRE FABRIC WRAPPING SYSTEM BASED ON A PROGRAMMABLE LOGIC CONTROLLER AND ASSISTED BY A HUMAN MACHINE INTERFACE*.

Fitranto, L. (2018). *DESIGN, CONSTRUCTION AND CREATION OF VITRAN BEVERAGES SEMI-AUTOMATIC FILLING AND CAPPING MACHINE* (p. 98). DEPARTMENT OF MECHANICAL ENGINEERING, Faculty of Industrial Technology, Sepuluh Nopember Institute of Technology.

Lesmana, A. R., & Budijono, P. (2021). *DESIGN OF AUTOMATIC VALVES IN GRAVITY SYSTEM FILLING MACHINES FOR GRAIN (RICE) MATERIALS*. *9*(02).

Pakpahan, E. P., Saragih, A., & Shintya, D. (2022). *Automatic Liquid Pump Product Design*.

Pammungkas, S. A. Y. (t.t.). *Filling of milk cream on PLC based ice cream cups*.
Pembudi, R. G., Pangestu, P. D., Salim, M. N., Falah, A. N. E., & Saputra, R. E. (2022). *Design and build soy milk making machine equipped with automatic packaging*.

Syarif, A., Harianto, & Puspasari, I. (2021). Rancang Bangun Automatic Liquid Filling Machine Berbasis IoT (Internet of Things). *Journal of Technology and Informatics (JoTI)*, *2*(2), 72– 82. https://doi.org/10.37802/joti.v3i1.178

Zhang, D., & Li, S. (2015). Design and realization of liquid filling machine intelligent control system. *2015 IEEE International Conference on Mechatronics and Automation (ICMA)*, 1283–1288. https://doi.org/10.1109/ICMA.2015.723