Applying Programmable Logic Control (PLC) for Control Motors, Blower and Heater in the Rubber Drying Processing

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ABSTRACT

Rubber is the largest commodity in Indonesia. Rubber is traditionally processed and dried using bamboo hangers, manual arrangement of bamboo drying rubber, heat from firewood for drying chambers and large areas. This drying process has disadvantages, namely inconsistent drying time, non-uniform room temperature, unequal product quality, and unfriendly drying process. The solution is to overcome the automatic rubber dryer machine that is made using PLC to get the motor operating system for automatic rubber handling in the drying chamber, fixed drying temperature, small drying area, and fast-drying time. The experimental method is used for the automatic rubber drying process with PLC to control the movement of rubber in/out of the chamber dryer, heater, and blower for distribution temperature and other components. From the test results, it is found that the control system can work well at the voltage of each component of 220V, such as a sensor with a current of 0.21A and a stop time of 0.01s-0.3 seconds. The motor, heater, and blower are active (ON) at 220V with a current of 8.27A. The heater requires a current of 1.99A for active (ON) and an active blower (ON) with a current of 0.75A.

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1. INTRODUCTION

Rubber is a major commodity product in Indonesia. Rubber plantations spread in several regions in Indonesia require a rubber processing process to meet the criteria or standards of dry rubber. The process of rubber processing is done traditionally by scraping the raw rubber from the tree, collected in a reservoir, and processed into a creep or SIR form. The dry quality of rubber (SIR) is very important as part of the acceptance of processed rubber products. Like quality rubber, SIR 1 has the criteria such as not having air bubbles on the inside of the dry rubber, and its color is clear. Several requirements must be considered to obtain rubber with SIR 1 quality, namely the drying room temperature in the range of 30°C -60°C, the availability of an adequate heat source in the drying chamber, and the process of adjusting the position of the wet rubber in the drying room.

The process of manually drying wet rubber into dry rubber with SIR quality requires several stages, namely collecting the wet rubber, installing it on bamboo hangers, inserting the wet rubber trolley into the drying room, heating the drying room to 30°C (for three days) and fourth day to seven days with a temperature of 60°C and followed by process of smoking or spraying liquid smoke [1]. The resource of thermal energy is obtained from firewood flowing into the drying chamber. The process of controlling the heat and checking the temperature in the drying chamber is done manually by installing a thermometer on the wall of the drying chamber. This makes it difficult to obtain uniform temperature measurements in the dryer chamber. It is done after seven days of the drying processing in the drying room to check the condition and quality of the rubber. From the results of the inspection of the dry content of the rubber, if there are no air bubbles on the rubber, then this meets the quality of SIR 1. But if there are some air bubbles that appear, insert the rubber, the quality of the rubber become decreases to the quality of SIR 2 and so on. This is very detrimental to the rubber company as some rubber that does not meet the desired requirements will be rejected by the ordering company.

Manual rubber drying processing has several disadvantages, namely inconsistent drying time, non-uniform room temperature, irregular rubber arrangement, requires a lot of bamboo for rubber hangers, unequal product quality, large drying area, and unfriendly drying process for the environment. The solution is to overcome the automatic rubber drying machine using PLC that is applied to control the system motor of automatic rubber dyer setting in the multi-storage room, fixed drying temperature, small drying area, and fast-drying time. The PLC will control the rubber drying process by regulating the movement of rubber in and out using a motion sensor, arrangement of rubber in the drying chamber, regulating the heating temperature in the drying chamber by activating the heater or blower, and so on. PLC has been used in many control systems such as rotary dryers for waste liquid processing, food processing, automotive part processing and etc. [2-17]. PLC application for the process control system or machine can be seen in pure milk processing using Omron CPM1A PLC, paint production process with TWIDO TWDLMDA20DTK PLC, Omron CP1L PLC as a control in moving goods into boxes, and others [7-10]. In addition to PLC, the control system can also be done using Arduino Uno, AT Mega, and others [18]. The control system in the rubber dryer machine uses PLC because it has advantages such as easy installation and maintenance, does not require a complicated wiring system, and so on [2].

The experimental method was used for an automatic rubber drying process with PLC to control the movement of rubber entering/leaving the chamber dryer, temperature, and other components such as heater and blower.

In this study focus on the control of component rubber dryer such as motor, blower, heater for rubber drying processing using Zelio Smart PLC, regulate the movement of rubber in and out, activation of heater and blower to regulate the temperature in the drying chamber, and arrange the arrangement of rubber in the drying chamber. The parameters to be adjusted are the room temperature between 30°C to 60°C, the voltage of activation of the heating or cooling media if the temperature is reduced or excessive, set the time to enter the drying chamber.

2. RESEARCH METHOD

An experimental method has been used in this research by making a control system component rubber dryer machine using Zelio smart PLC. PLC application for the process control system or machine can be seen in pure milk processing using Omron CPM1A PLC, paint production process with TWIDO TWDLMDA20DTK PLC, Omron CP1L PLC as a control in moving goods into boxes, PLC for energy research, industrial control applications, and monitoring of plants, water, and wastewater management control, PLC for the control system in manufacturing automation, PLC for product sorting and packaging based on color detection and others [4-11].

The automatic rubber drying machine control system using PLC consists of designing software by creating a ladder program. The flow of this research process can be seen in Fig. 1. The drying process is started by observing the rubber drying process manually in a rubber processing and drying company, followed by a literature review for the design and design of automatic rubber dryers, design, and manufacture of ladder programs for the work of dryer machine components such as sensors, motors, and gearboxes, heaters, and blowers. Continue with the ladder program input into the PLC connected to the rubber dryer component network. Start by pressing the start button to start the rubber dryer. When rubber is detected by the rubber reception sensor (sensor 1), sensor one will tell the PLC to order the motor and gearbox to be active.

The working time of sensor 1 to work is adjusted according to the measurements of -1 to the 9th rubber dimension used plus a second detector sensor of the rubber long end detector -1 to nth. Next, the motor and gearbox will move the rubber towards the entrance to the drying chamber, where there is sensor 3. Then the rubber is arranged to fill the drying chamber, and after sensor three detects all the rubber fills the drying chamber, the heater or blower will be active to distribute heat to the chamber drying. The heater will be active if the temperature is below 30°C. The heater will turn off when the temperature is above 600°C. When the heater is off, the blower circulation will actively disperse the hot air in the drying chamber until the dryer room temperature is evenly distributed at 300°C-600°C. If the temperature is above 600°C, the evacuation blower will blow air out of the drying room until the drying room temperature is maintained at 300°C-600°C. The process lasted for seven days according to the drying time of the company, and the quality of the rubber was measured visually and the moisture content.

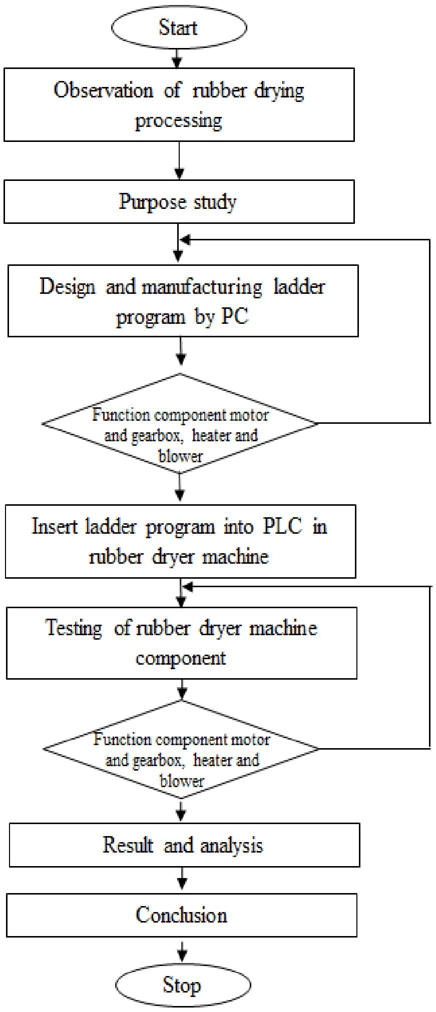
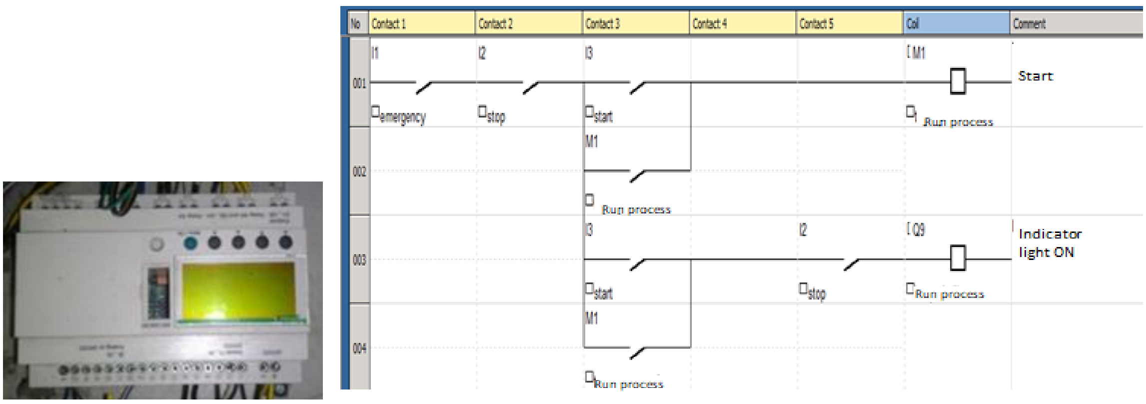


Fig. 1. Flowchart of research activity

In this study, PLC SR3B261FU Zelio smart relay types are used for the control system in the rubber dryer machine, as shown in Fig. 2(a). with input voltage specifications of 24V, current 4mA, and input number 16, 10 relay output and output voltage limits of 5-30V_{DC} and 24-250V_{AC} as shown in Table 1. The PLC programming using the ladder program is shown in Fig. 2(b).



(a) PLC (b) Ladder program PLC

Fig. 2. PLC Zelio Smart Relay SR3B261FU

Rubber drying machine components consist of drying chamber, sensor insert and out motion rubber and temperature sensor, chain drive motor, rubber hook chain, heater, blower, thermometer, gear, PLC, and others. The components of this rubber dryer can be seen in Fig. 3. The details of the components of this rubber dryer are:

1. Drying chamber
   The dryer chamber has specifications of 4000mm length, 2000m width, and 2000m height. The dryer chamber is made of a stainless steel frame with a size of 40x60mm. The walls of the dryer chamber are made of glass or plastic.
2. PLC
   The PLC used by the Schneider is a type of smart Zelio relay with the shape and specifications that can be seen in Table 1.
3. Motor and gearbox
   The motor and gearbox used has specifications: power 0.12-4KW and rotation of 1400rpm, as can be seen in Fig. 4 and Table 2.
4. Shaft and sprocket
   The shaft is the handle of the sprocket that will move the rubber hook chain. The shaft and chain are made of steel.
5. Proximity and temperature sensors
   A proximity sensor is used to read the wet rubber so that the PLC will activate the motor and the gearbox moves to bring the rubber to the dryer chamber.
6. Blower and heater
   Blowers are used to circulating air in the drying chamber and remove air from the drying chamber if the temperature of the drying chamber is more than 60^{o}C. The heater serves to transfer heat to the drying chamber if the air temperature is less than 30^{o}C.
7. Chains and hangers for rubber
   Chains and hangers serve to attach the wet rubber and carry it into the dryer chamber.

Table 1. Specification of PLC Zelio Smart Relay SR3B261FU

No	Item	Value
1	Product or component type	Modular Smart Relay
2	Local display	With
3	Clock	With
5	Use rate supply voltage	24V
7	Discrete input number	16
8	Discrete input voltage	24VDC
9	Discrete input current	4mA
10	Analog input number	6
11	Analog input range	0 – 24/ 0 – 10V
12	Number of outputs	10 Relay output
13	Output voltage limits	5-30VDC (Relay output) 24- 250VAC (Relay output)

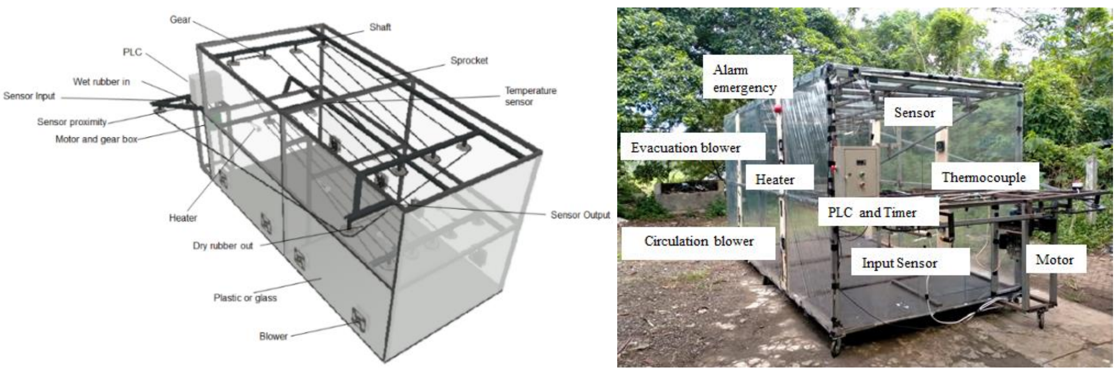


Fig. 3 Rubber dryer machine and components

Fig. 4 Motor and gearbox

Table 2. Specification of motor *Yuema helical gear box*

Type	CHCFP (IEC)
Sizes	01-01-03-04
Rpm max (1400rpm)	500Nm
Ratio	3.66 – 54
Power	0.12– 4kW

The temperature measuring points using digital thermometers in the rubber dryer chamber are located at the front, top, bottom, left, and right of the drying chamber. The installation arrangement of the rubber dryer temperature gauge can be seen in Fig. 5.

The working principle of this rubber dryer is that the wet rubber material detected by the input sensor will provide information to the PLC to activate the actuator motor to bring the wet rubber to the dryer chamber. Once the wet rubber is arranged and full in the rubber drying chamber, then the rubber drying system starts operating. The initial heat of the drying system is obtained from the sun's heat trapped in the drying chamber, thus increasing the temperature in the drying chamber. The temperature in the drying chamber is set between 30°C into 60°C (50°C) [19]. If the temperature in the drying chamber is below 30°C then the heater will be active to transfer heat to the drying chamber using an air jet blower. If the temperature is above 60°C, the blower will be active to circulate air out of the drying chamber. At night the heating system of the drying chamber uses a heater with an air temperature setting between 30°C into 60°C. The process of drying wet rubber is done for seven days by measuring the moisture content produced by the dry rubber. Once the moisture content of the rubber is dry, the PLC will command the active motor and remove the rubber from the drying chamber. After that, the dimensions, weight, and quality of the rubber are measured visually by a lighting process so that air bubbles in the dry rubber can be seen. If a lot of air bubbles are trapped in the dry rubber, the quality of the rubber is low, and on the other hand, if there are no air bubbles, the quality of the rubber is good (SIR 1). Fig. 6 shows the quality of dry rubber visually inspected using illumination.

Fig. 5 Position sensor of temperature using thermocouple

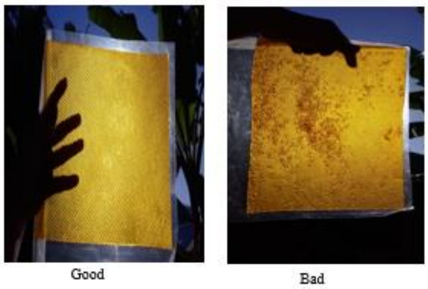


Fig. 6 Quality of SIR rubber

2.1. Ladder Program of PLC

The automatic rubber dryer control system with PLC using ladder program. The stages of creating a ladder program are:

1. Make a blog diagram of the automatic rubber dryer control system.
   The blog diagram of the automatic rubber drying machine control system can be seen in Fig. 7. As shown in Fig. 7, wet rubber is hung on a hook hanger chain and detected by an input sensor to enter the drying chamber through the activation of the motor and gearbox. The motor moves a chain containing rubber to the drying chamber until it is arranged to fill the drying chamber. Once the wet rubber is fully stacked in the drying chamber, the rubber drying process will run with the temperature setting between 30^{o}C into 60^{o}C and drying time for seven days. Once the rubber is dry, the proximity sensor will signal to the PLC to remove the rubber from the drying chamber.
2. Create a ladder program using a PC and insert the program into the PLC consisting of ordering rubber, voltage ON/OFF, indicator light ON/OFF, activation motor and gearbox ON/OFF, timer ON/OFF, heater and blower ON/OFF, and setting time for drying process at seven days.
3. Then the control program on the PLC is activated on the rubber dryer to move the machine components, and component performance tests are carried out, which include: the working test of sensor 1 (when rubber is first detected), sensor 2 (when rubber is detected moving into the dryer room), sensor 3 (when the first rubber is in the drying chamber) in the form of working voltage and pause, motor motion test and gearbox, heater, circulation blower and evacuation in the form of voltage-current ON and OFF.

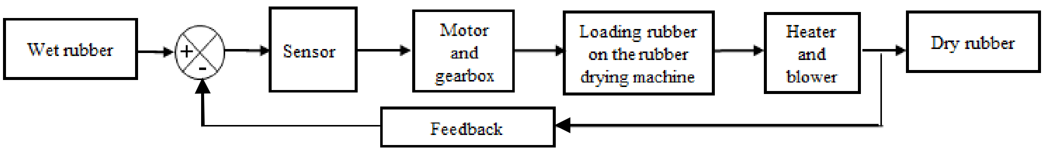


Fig. 7. Block diagram of the control system of rubber dryer machine

3. RESULTS AND DISCUSSION

In testing the automatic rubber dryer machine, using PLC greatly helps the rubber drying process to produce rubber with SIR 1 quality. SIR 1 rubber quality has product criteria with rubber drying result without air bubbles on the inside of the rubber. If the dry rubber has air bubbles in it, the quality of this rubber will be low and can be processed back into creeping rubber. The result of automatic rubber drying using PLC has obtained results in accordance with the quality of SIR 1 rubber where it starts by making ladder program on PC, followed by transferring ladder program into PLC and operating an automatic rubber dryer machine using PLC.

The results of manufacturing and testing of ladder program for automatic rubber drying machine control system using PLC can be seen in Fig. 8. Fig. 9 shows the PLC ladder program for the working condition of rubber dryer machine components where in the figure shows a ladder program inserted into a PLC system, as shown in Fig. 8, which can serve to regulate the movement of wet rubber into the drying chamber until the dry rubber exits in the dryer chamber (see Fig. 9). They are starting from the input voltage when the wet rubber is hung on a hook hanger on the chain, followed by the PLC commands. The motor and gearbox move to bring the wet rubber to the drying chamber and fill the drying chamber according to the dried rubber capacity. Once the rubber fills the drying chamber, the drying process is started, and the drying time is adjusted to seven days. During the seven days, the heater actively conducts heat to the drying chamber by using a circulation blower in case of the heat from solar energy is cannot enough to supply heat from a temperature of 30^{o}C to 60^{o}C. When the drying room temperature exceeds 60°C, the evacuation blower will work to remove hot air in the drying chamber. After seven days of drying time, the PLC control system will activate the motor and gearbox to remove the rubber from the drying chamber.

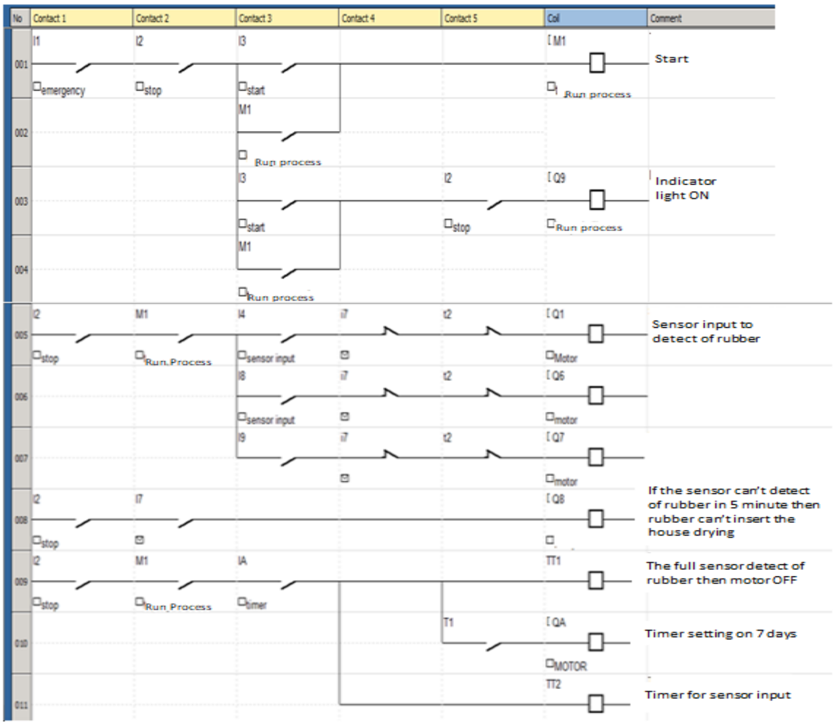


Fig. 8 Ladder program PLC for the control system of rubber dryer machine

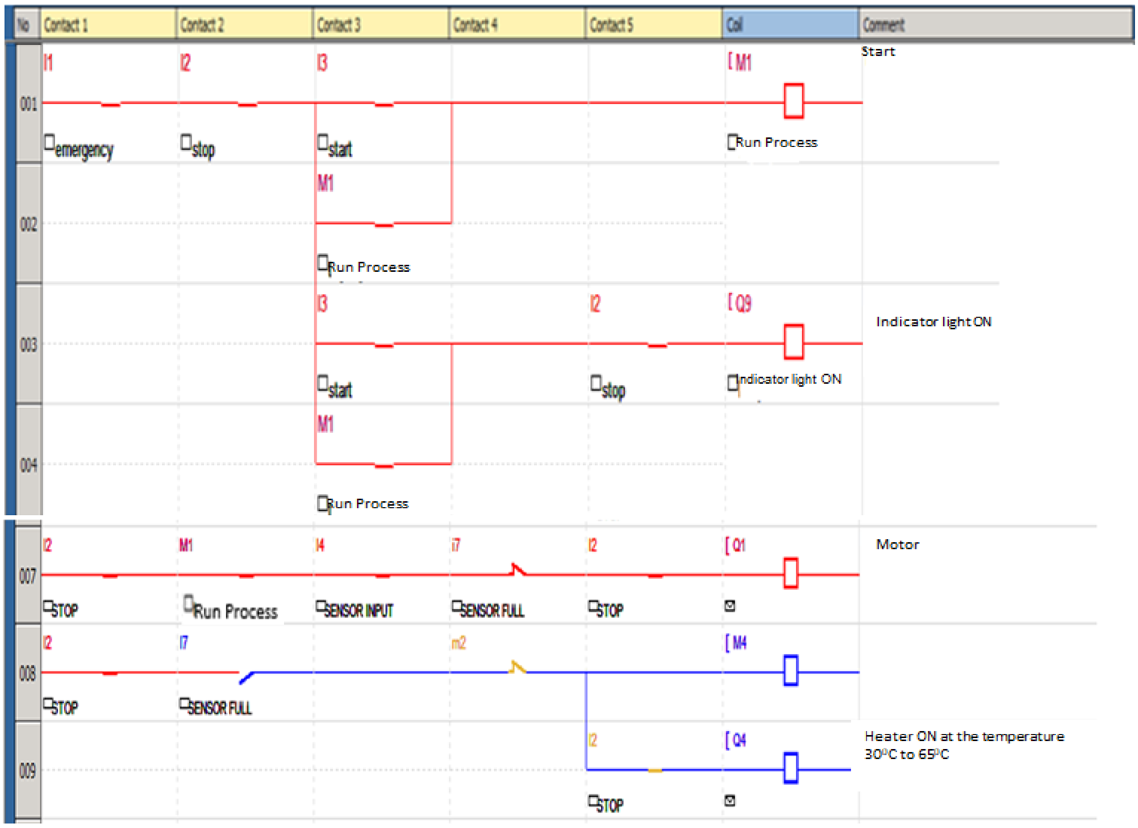


Fig. 9 Testing of ladder program PLC for function component control system of rubber dryer machine

Table 3 shows the arrangement of rubber inlet and test results of distance sensor with rubber dimension 500x400x5 (mm), which can be seen that rubber-1 movement requires voltage 220V and current 0.21A. The working time of sensor 1 to detect rubber entering the drying chamber door is 3.38s, waiting time 0.1s. Sensor 1 will provide information to the PLC to activate the motor to pull the rubber towards the entrance to the drying chamber. Sensor 2 detects the movement of rubber-1 towards the entrance of the rubber drying chamber to the dryer chamber with a working time of 3.38s and a waiting time of 0.14s. Sensor 3 showed rubber movement to the drying chamber for 3.36s and a waiting time of 0.1s. On the rubber-2 line, it can be seen that sensor 1 uses a working time of 3.35s and a waiting time of 0.2s to detect the arrival of rubber and provide information to the PLC to activate the drive motor until the rubber-2 moves towards the entrance to the drying room, the second sensor requires the same time as sensor one and sensor 2 require a companion time of 3.38s and 0.1s waiting time for the rubber to enter the drying chamber.

The 3rd rubber required a time for sensor 1 to detect the arrival of the rubber at 3.38 s and a waiting time at 0.11s. For sensor 2, the working time of transferring the rubber to the drying chamber is shorter, i.e., 3.35s and 0.11s, and sensor 3 requires 3.37s and 0.12s to detect the 3rd rubber already present in the drying chamber. The entry of the 4th rubber into the drying chamber is detected by sensor 1 with a working time of 3.38s and 0.15s of waiting time. As sensor 2 moves the 3rd rubber into the inlet chamber for 3.37s and 0.2s of waiting time of sensor three stacks the rubber in the drying chamber with working times of 3.37s and 0.12s. For the fourth to ninth rubber movements, it can be seen that the working time ranges from 3.35s to 3.39s, and the waiting time is 0.1s to 0.4s for sensor 1. On sensor 2, it is 3.34s-3.39s and 0.1s-0.2s for waiting for time, and sensor 3 takes 3.35s -3.38s and a waiting time of 0.1s.

On the 9th rubber, the 1-time sensor to detect and provide information for the rubber entering the PLC to activate the motor is 3.35s and 0.4s for the waiting time. Meanwhile, sensor one and sensor 3 have working times of 3.38s and 3.37s with waiting times of 0.1s.

Table 3 Testing data of sensor proximity with dimension rubber 500 x 400 x 5 (mm)

Number of rubber	Length (mm)	Voltage (V)	Current (A)	Time of rubber insert on the drying house (s)					
				Sensor 1		Sensor 2		Sensor 3	
				ON	OFF	ON	OFF	ON	OFF
1				3.38	0.10	3.38	0.14	3.36	0.10
2				3.35	0.20	3.35	0.20	3.38	0.10
3				3.38	0.11	3.35	0.11	3.37	0.12
4	500	220	0.21	3.38	0.15	3.37	0.20	3.35	0.10
5				3.39	0.10	3.36	0.11	3.35	0.10
6				3.37	0.20	3.34	0.10	3.37	0.10
7				3.38	0.21	3.39	0.17	3.38	0.10
8				3.39	0.13	3.38	0.10	3.36	0.10
9				3.35	0.40	3.38	0.10	3.37	0.10

The results of performance test each component of the automatic rubber dryer machine with PLC control system obtained:

1. Performance test data of proximity sensor 1, sensor 2, and sensor 3 using wet rubber with dimension 500x400x5 (mm) show that the function of the proximity sensor works at a voltage of 220V with a current of 0.21 A. The time required to detect rubber and move in the drying chamber is 3.35s – 3.39s with a stop time interval of 0.1s – 0.3s. This indicates the sensor is able to function to detect and provide information to the PLC to activate the motor, and the gearbox moves the rubber hanger hook chain to the dryer chamber.
2. The AC motor test data show that the motor is active (ON) at a voltage of 220V with a current of 8.27A and stop (OFF) at a current of 0A, as shown in Table 4.
3. The heater test data show that the heater requires a current of 1.99A at a voltage of 220VAC for active (ON) and stop (OFF) at a current of 0A, as shown in Table 5. The heater is arranged to work on a rubber dryer with a working temperature of 30°C into 60°C. If the temperature in the drying chamber is less than 30°C then the heater will be active (ON) using a current of 8.27A and other hands if the drying room temperature is more than 60°C, then the heater stops (OFF), and the evacuation blower will actively remove air from the drying chamber rubber.
4. Blower test data show that the motor will be active (ON) at a voltage of 220V with a current of 0.75A and stop (OFF) at a current 0A, as shown in Table 6. The blower used serves as a conduit of hot air in the

drying chamber until dissipated evenly (the constant temperature at 40°C-50°C) and distribute hot air out of the drying chamber if the drying room temperature exceeds 60°C.

Table 4 Testing data performance of motor AC

Function	Voltage (V_{AC})	Current (A)
ON	220	8.27
OFF	220	0

Table 5 Testing data performance of heater

Function	Voltage (V_{AC})	Current (A)
ON	220	1.99
OFF	220	0

Table 6 Testing data performance of blower evacuation

Output	Function	Temp (°C)	Output (V_{AC})	Current (A)
Blower 1	ON	45-100	220	0.75
	OFF	<43	220	0
Blower 2	ON	45-100	220	0.74
	OFF	<43	220	0
Blower 3	ON	45-100	220	0.75
	OFF	<43	220	0
Blower 4	ON	45-100	220	0.75
	OFF	<43	220	0

As shown in the testing results of proximity sensors 1, 2, and 3, there is a difference in the stop time value of the input sensor and the rubber displacement from 0.01s to 0.3s, especially on sensor 1. In sensor 2, it has similarities value with sensor one but different for sensor 3, where on sensor 3, the stop time values of the input sensor and the rubber number displacement 1 to 8 are almost the same. This is due to several conditions, namely: the sensor is affected by external light so that the sensor cannot detect the incoming rubber. In addition, this is also due to the nature of the sensor having a delay in reading the detected object.

The testing results of the wet rubber drying process using solar energy showed a temperature distribution from 06:00 to 22:00 between 27°C to 46°C with 53-224 lux sunlight, as shown in Fig. 10. This indicates that with the use of the control system on the rubber dryer machine, the same working temperature will be obtained (40°C-50°C) with the temperature setting range using PLC 30°C-60°C.

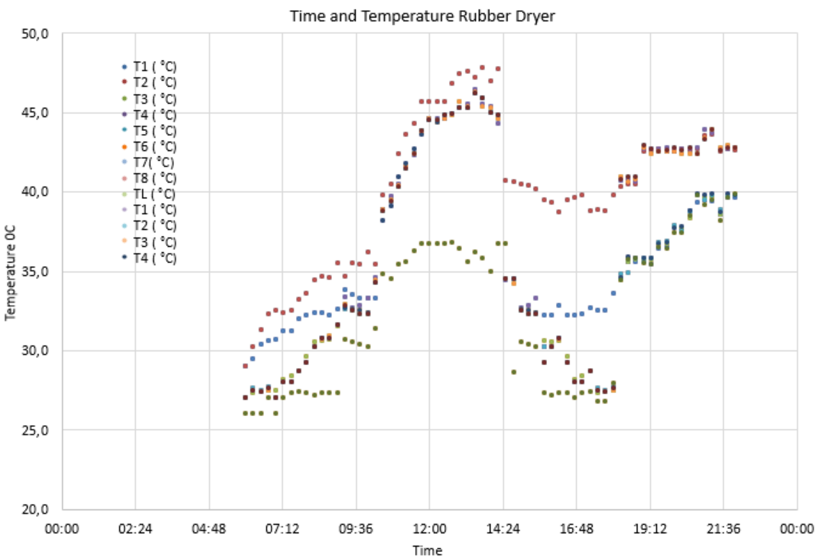


Fig. 10 Result testing of time and temperature distribution in the drying chamber

The process of drying the rubber and the resulting product can be seen in Fig. 11. The result of the rubber using this automatic rubber dryer machine shows good quality where there are no air bubbles in the dried rubber. Compared with the results of rubber drying based on standards from Company X (see Fig. 6), the drying result with this rubber dryer has met the standard requirements.

a. Dry Rubber using rubber dryer machine

b. Dry Rubber using traditional dryer PT. X (SIR 1)

Fig. 11 Quality result testing of dry rubber

4. CONCLUSION

From the data experimental testing of automatic rubber dryer control system using PLC it can be concluded that the control system can be working fairly with a voltage of each component 220V such as Motor, heater, the blower is active (ON) with the current of 8.27A and stop (OFF) at a current of 0A. The heater requires a current of 1.99A for active (ON) and stop (OFF) at a current of 0A, and lower will be active (ON) with a current of 0.75A and stop (OFF) at a current 0A. The performance sensor on the components of the automatic rubber dryer machine using PLC works at a voltage of 220 V and current of 0.21A. The time required to detect rubber and move in the drying chamber is 3.35s – 3.39s with a stop time interval of 0.1s – 0.3s. The automatic rubber drying machine control system using PLC can work well and produce quality rubber according to the quality standard for SIR1.

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