Development of Control System for *Keropok Keping* Drying Machine

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Abstract. This research is focused on the development of a control system for the *keropok keping* drying machine by using programmable logic controller (PLC) as the controller. The control panel and human machine interface (HMI) were developed for the machine. Experimental study was conducted to validate the HMI speed data by the control panel speed display. The evaluation of the duty cycle (%) and current flow (amp) effect to the motor and fan speed were also conducted. The results showed that around 1 - 30 % and 1 - 3 % differences of the speed readings were recorded by the HMI for the motor and fan respectively. The percentage difference needs to be controlled as small as possible to ensure the HMI speed readings are more accurate. The linearity of the current flow curve to all duty cycle can be observed. The flow (amp) increases when the speed of dryer motor and fan increases. The development of the control system is expected to improve the operation of the *keropok keping* drying machine.

1 Introduction

Keropok keping is a dried crispy food product relatively popular in Malaysia and South-East Asian countries. Currently, its manufacturing is mostly practiced in small scale industry [1]. In Malaysia, the *keropok keping* industry is widely operated in coastal areas in the state of Terengganu, Kelantan, Johor, Kedah and some parts of Pahang due to high seafood supply, high temperature and windy area that contribute to the sustainability of the industries [3].

Ingredients for making of the *keropok keping* are starch or sago flour, fish, squid, prawn or shrimp and a little of seasoning such as pepper, garlic, salt, sugar and monosodium glutamate (MSG). All the ingredients are mixed by using a mixer to obtain dough. The dough is formed into a cylindrical shape with a diameter around 6 to 10 cm and then is cooked by boiling or steaming. The cooked dough is drained, cooled and cut into the thin slices with thickness around 3 mm and then is dried under the sunlight [2].

The dried *keropok keping* obtained is considered as a half-finished product or an intermediate product. Then, the *keropok keping* has to be fried in hot oil to obtain the edible puffed cracker. In *keropok keping* industries, most of the production processes are implemented by semi-automated machines such as a mixer, grinding and slicing machine. However, the drying process still uses the traditional method. In existing method, the *keropok* is arranged and dried on a drying board called *pemidai* under the sunlight. The *keropok keping* is exposed to the heat and surrounding wind to be dried [3]. In order to improve the drying process, new rotary type of *keropok keping* drying machine was invented as shown in Figure 1.

In general machine operation, *keropok* with high level moisture is arranged and hold by a special holder inside the rotary drum which is the drum and supported by four rubber tires. The gear motor is utilized to transmit power to rotate the drum to produce anti-clockwise rotation. Air generated by the fan is flowing to vaporize the water from the *keropok keping* inside the rotary drum. The process is continuously performed until the moisture level in the *keropok keping* is considered low and suitable for packaging [3]

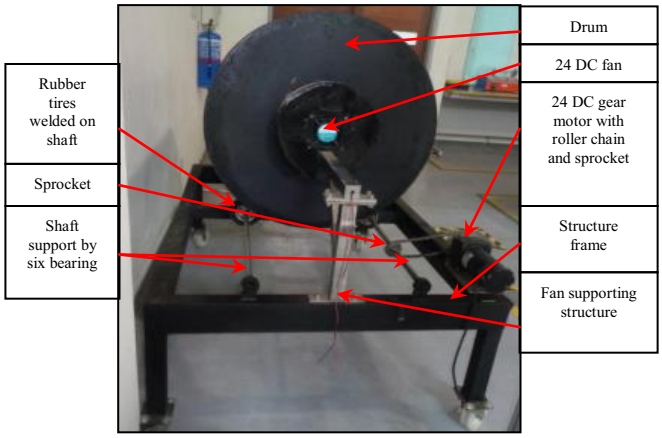

Figure 1: Rotary type of *keropok keping* drying machine [3]

However, the machine does not have any special system to control the dryer operation. All tools and machines need an appropriate control system to work. Otherwise it will be difficult to complete the task designation accurately. Control system is needed in order to guide, instruct and regulate tools and machines.

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Common control system includes mechanical, electronic electrical and computer aided. A system usually contains three main parts which are input, process and output.

The objective of this paper is to develop a control system for the *keropok keping* drying machine by using PLC as a main controller. The purpose of the control system development is to improve the machine operation. The current machine design does not have a control system to instruct and regulate the machine during the drying process. Based on the machine design, the speeds (rpm) of motor and fan has significant effect to the effectiveness of the dryer. The drying rate of the *keropok keping* is depends on the variation of the rotation speed for both of components. However, in the current design, the control system for the machine is not developed. This situation may cause difficulty to the users to control the machine. It is necessary to develop a user friendly control system to ensure that the machine can work in a proper way.

2 Methods

2.1 Electrical design

Design of Electrical Block Diagram: A block diagram is a diagram of system components that are represented by blocks. It is connected by lines to show the relationships of the system. The block diagram is widely used in electrical hardware and software design. The block diagram is typically used for higher level, less detailed descriptions that are intended to clarify overall concepts without concern for the details of implementation. In this method, block diagram for the dryer control system was developed by using selected electrical components. The diagram can be used as a basic primary input reference before drawing the detail electrical wiring diagram for the dryer control system.

Design of Control Panel: The electrical control panel is a cabinet for electrical or electronic equipment such as mounted switches, knobs and displays. It is used to prevent electrical shock to the equipment, users and to protect the contents from the environment. The panel is also known as an electrical enclosure. Electrical enclosures are usually made from rigid plastics, metals, particular stainless steel, carbon steel and aluminum. Mechanical design using computer aided design software is used to represent the dimension of the control panel, components arrangement and type of the design. The process is conducted to ensure that all the electrical components and wiring connection can be fixed into the design during fabrication work.

2.2 Control design

Controller Unit Selection: The significant unit in intelligent systems is the controller unit which allows defining complex applications and also implementing practical interface [4]. There are several types of controllers which are being used in various engineering processes such as Programmable Logic Control (PLC), and micro controller (PIC). Almost any production line, machine function or process can be significantly enhanced using this type of the control system. For this research, OMRON PLC was selected as the main controller. The PLC is considered as an economical controller for the complex system. The benefit in using PLC is the ability to modify and replicate the operation or process while collecting and communicating vital information. Besides, the controller is also easy to program and the durability and reliability of the components have made PLCs likely to operate for several years [5].

Design of Ladder Diagram: The PLC ladder diagram was created by using CX-Programmer. CX- Programmer is the programming software for all Omron's PLC series, which is fully integrated into the CX-One software suite. CX-Programmer includes a wide variety of features to speed up the development of PLC programs. Advantages of using this type of software are new parameter setting dialogues to reduce setup time. The development of PLC programs is also simple with drag and drop configuration [6]. In the ladder logic development, the important part is to determine the dryer sequence of operation. After that, all external I/O devices for the dryer must be determined and assigned number corresponding to the I/O number before uploading into the PLC hardware.

Simulation: For the simulation purpose, CX-Designer software was utilized to test the functionality of the created ladder diagram. Similar to CX-programmer, this software is also fully integrated into CX-One software suite. In the simulation method, development of the Simulator Control Panel (SCP) is needed to simulate the created ladder diagram. The SCP design is used for the simulation purpose only. In the SCP, all I/O devices must be developed and represented in the software screen based on I/O created from the ladder diagram. The simulation is important to ensure that the created ladder diagram can fully function without any problem. Besides, the simulation is able to monitor the I/O progress and also can detect malfunctioning of the I/O. Through the simulation, the modification of the ladder diagram can be done if the diagram has some problem or mistake before it is uploaded into the PLC hardware.

Design of wiring diagram for PLC connection: A wiring diagram is a simple visual representation of the physical connections and physical layout of the electrical system or circuit. In this method, the wiring diagram is developed to show how the electrical wires are interconnected and where dryer fixtures and components may connect to the system. The idea of wiring diagram is based on the developed block diagram. The diagram is important to assist in developing the control system during fabrication work. For this purpose, an electrical computer aided design is used to develop the wiring diagram for the dryer control system.

Design of Sensory Devices: Sensors are common components for converting physical characteristics to electrical value. In the drying machine, two types of sensors were utilized for recording motor and fan speed and also temperature and humidity inside of rotary drum. Suitable sensor and controller must be selected properly in order to obtain an accurate data from the sensor during data acquisition (DAQ) process.

2.3 Design of Human Machine Interface (HMI)

The design of Human Machine Interface (HMI): A Human Machine Interface (HMI) is an interface for providing the means of controlling, monitoring, managing and visualizing device processes [7]. Visual Basic 2008 was used to design the HMI for the control system. An external controller is needed as a medium to interface between HMI and PLC. Therefore, the controller has to be developed to ensure the HMI can fully function.

2.4 Prototyping and Testing

A prototype of the control system was fabricated base on all design methods. The fabrication includes mechanical, electrical and electronic work. Finally, the control system is tested to ensure the functionality of the overall system and to validate the data recorded by the sensors.

3 Results and discussion

3.1 Electrical design

Electrical block diagram: The developed blocks diagram for the dryer controller is shown in Figure 2. The system can be controlled by two types of methods. Firstly by using the Control Panel (CP) and secondly by using the Human Machine Interface (HMI) which is assisted by an external controller.

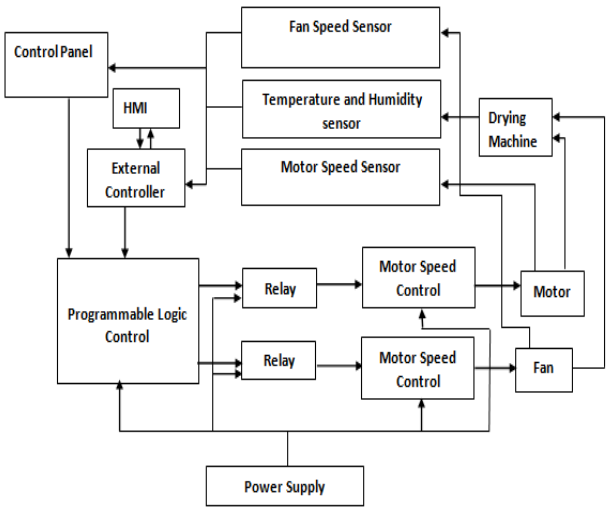

Figure 2: Block diagram of drying machine control system

The power supply was given to the PLC as well as to both motor speed controls. In the design, two relays were used as a switching component for the motor and fan. Two types of sensors were attached into the design. The sensors are motor speed and temperature/humidity sensor. The motor speed sensor is used to measure the speed of the motor and fan during operation while temperature sensor is used to measure temperature and humidity inside the rotary drum.

Control Panel: Figure 3 shows the 3D model of the control panel. The panel consists of two main parts namely, the electrical enclosure and the structural frame. Electrical enclosure was utilized to mount all switches, knobs, and displays that are used in the control panel. It is also used to protect the contents inside of the enclosure such as one unit PLC, two units 24VDC relays, two unit 24V DC power supplies and one unit miniature circuit breaker (MCB) from the environment. While the structural frame is used as a support stand for the enclosure to ensure that the panel is ergonomic and easy to control by the user.

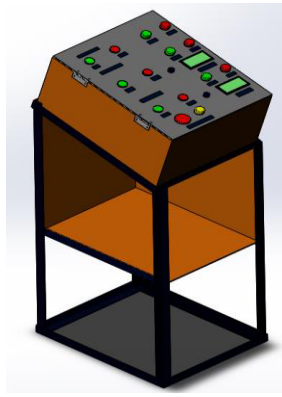

Figure 3: CAD model of control panel for *keropok keping* drying machine

The panel can be divided into five sub controls including main switch, motor switch, fan switch, emergency and automatic switch. The main switch is used to activate or deactivate the overall system in the control panel. Both motor and fan control is used to switch ON or OFF the motor and fan respectively. For safety purposes, an emergency switch is allocated to the control panel to shut off the overall system if any undesirable condition happens during the machine operation. Automatic control is also designed for the machine. Therefore, automatic switch rotary type was placed at the right of the control panel to provide an auto signal to the controller.

Motor and fan speed are important parameters that need to be controlled in the drying machine. Pulse-Width Modulation (PWM) motor speed controls with potentiometer were installed for both motor and fan in the control panel. It is the feasible approach in motors' and speed control [8]. The PWM approach will assist in achieving different speed requirements for the motor and fan. It uses duty-cycle principle and average voltage for controlling the motor and fan speed smoothly. The

different speed levels range between 0 to 100% of maximum speed [9].

3.2 Control design

Controller Unit Selection: OMRON PLC CJ series model CJ2M-CPU11 was selected as the main controller device for the system. The PLC unit can be categorized as a modular type PLC or rack mounted units due to the power supply, CPU and I/O interface comes separately [10]. The advantages of using this type of PLC are the PLC have far more memory and has the capability to store a higher volume of information. Besides, the PLC also has the capacity to accomplish more complex processes. The type of PLC was used in the control panel can be illustrated in Figure 4.

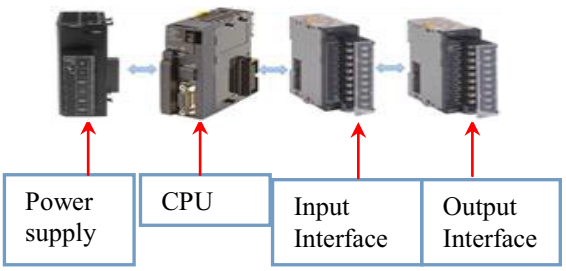

Figure 4: PLC OMRON CJ2M-CPU11 modular type

The controller (PLC) is used to give the switching commands to all input and output devices for the drying machine. PLC hardware setup is very important before creating a ladder diagram. The detail PLC setup can be illustrated in Figure 5. In the PLC, two types of cables can be used to upload the program into the PLC hardware. The cables are RS232 or USB cable. However, both of the cables need different setup before it can be used. For this research, the USB cable was selected as the interface cable between computer and PLC due to easy setup compared to the with RS232 cable.

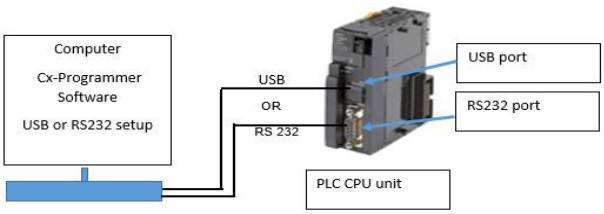

Figure 5: PLC hardware setup

Dryer Control Sequence: The algorithm used in *keropok keping* drying machine control system technique is shown in Figure 6. The control was programmed in either automatic or manual operation. When the automatic switch is turned on, the timer starts and the drying process begins. The motor and fan will rotate respectively and the duration of the rotations depends on the timer setup in the ladder diagram. Pilot lamps were utilized as an indicator to represent each output operation. After the timer time out, all system is stopped. In manual operation motor and fan can be controlled independently by the user during the drying process.

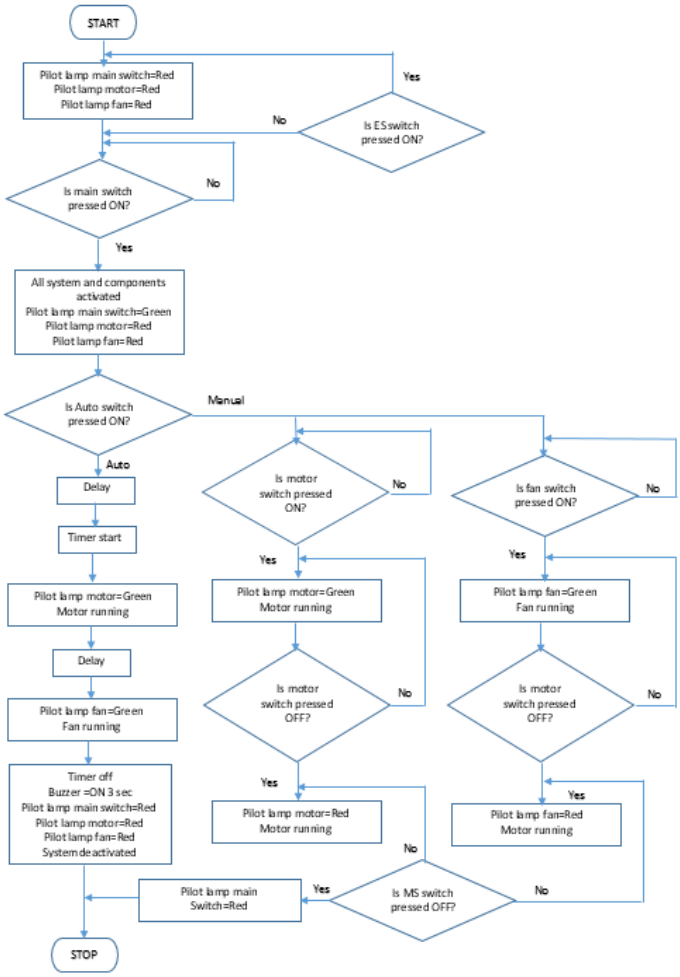

Figure 6: Algorithm for *keropok keping* drying machine control system

Assignment of Inputs and Outputs: After the system sequence of operation was determined, all the external input and output devices connected to the PLC must be assigned the addressing number corresponding to the input and output number. Table 1 shows the assignment of the inputs and outputs number to the PLC. The number is important before creating the detailed ladder diagram in the CX-Programmer software.

Table 1: Assignment number for Inputs and Outputs

Input	Address	Output	Address
Main Switch ON	I:0.00	PL Main switch ON	O:1.00

Main Switch OFF	I:0.01	PL Main switch OFF	O:1.01
Motor On	I:0.02	PL Motor switch ON	O:1.02
Motor OFF	I:0.03	PL Motor OFF	O:1.03
Fan ON	I:0.04	Motor	O:1.05
Fan OFF	I:0.05	PL Fan ON	O:1.06
Emergency Switch	I:0.06	PL Fan OFF	O:1.07
Auto Switch	I:0.07	Fan	O:1.09
		PL Emergency	O:1.10
		Buzzer	O:1.11

Simulation: Simulator control panel (SCP) was developed to simulate and test the functionality of the created ladder diagram. The panel can be shown in Figure 7. After the testing process completed, the diagram will be uploaded into the PLC hardware.

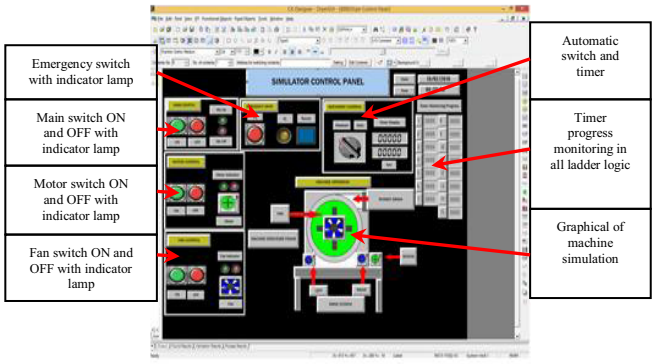

Figure 7: Simulator Control Panel (SCP)

Sensory Device: Architecture of sensory devices in the control system can be shown in Figure 8.

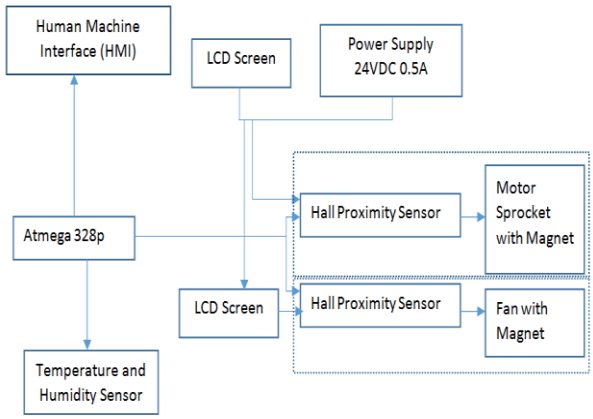

Figure 8: Architecture of sensor system

Atmega 328P microcontroller was used as a controller to all the sensors in the system. The controller also can be used as a data acquisition (DAQ) device through a serial communication port. The data then will be transferred to the HMI for recording process via receiving data command.

3.3 Human Machine Interface (HMI)

Human machine interface (HMI) for the drying machine can be illustrated in Figure 9. The HMI was created using Visual Basic Express 2008. However, the HMI needs to work together with an external controller.

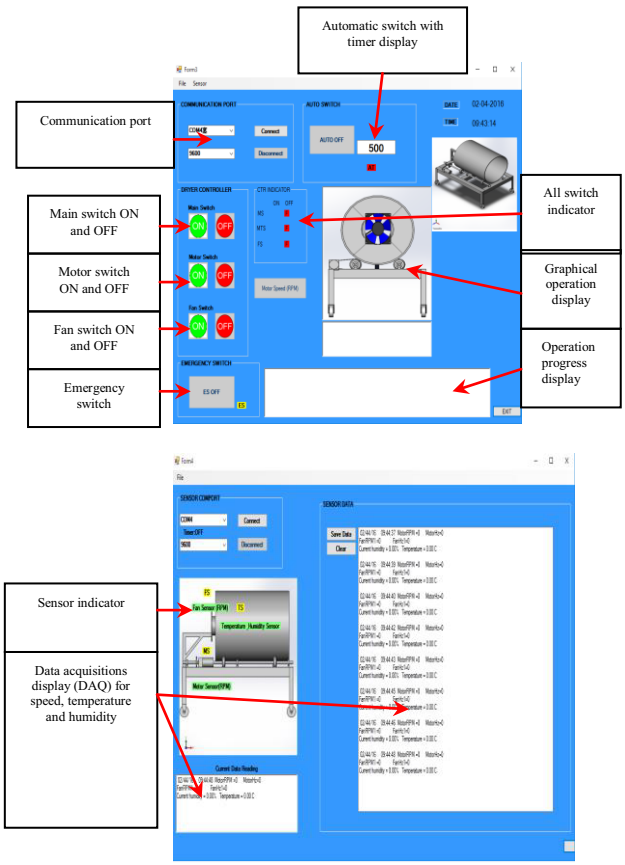

Figure 9: Human Machine Interface (HMI) for *keropok keping* drying machine with sensor data acquisition (DAQ)

The external controller was designed based on electronic relay module. The component consists of 12VDC relay, 10k Ohm resistor, IN 4007 diode, transistor 2N2222 and AT Mega328P as the controller. In the design, eight relay modules were developed.

3.4 Prototyping and Testing

The prototype of the control panel can be illustrated in Figure 10. The experimental study of the duty cycle (%)

effect to the dryer motor and fan speed was conducted. The testing was conducted without any load applied onto the motor. The study is conducted in order to know the relationship between the duty cycle (%) and current flow (amp) to the motor and fan speed (rpm). It is also done to investigate the minimum and maximum speed that can be achieved by the motor and fan without any load applied in the system. The speed of the control panel was used as the reference speed for the validation process due to the display is a real digital tachometer which was attached to the control panel but in the HMI, the speed reading is based on the equation written in C programming language.

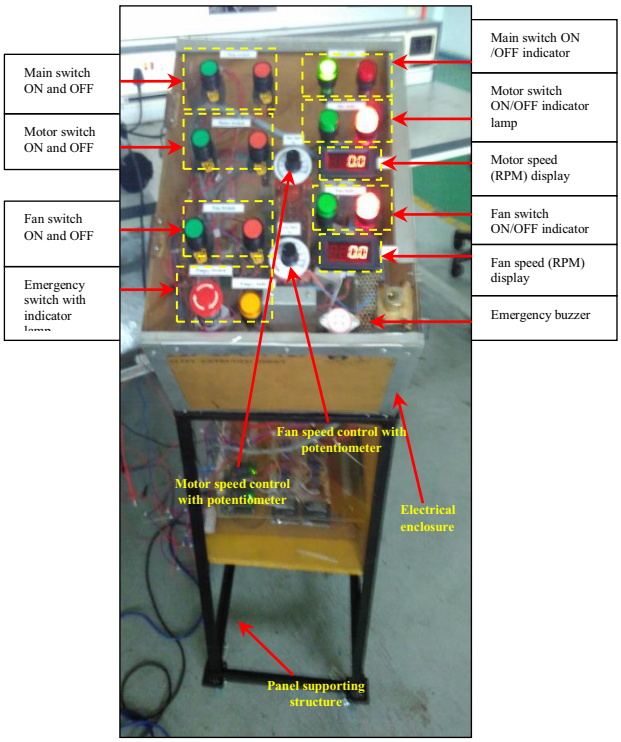

Figure 10: Control panel and HMI controller prototype

Measurement of the differences of the speed readings between both of the methods is very important to validate the HMI data reading. In order to obtain the current flow, a multimeter was fixed between the life wire of the motor and fan. The multimeter was setup in 10Amp measurement mode to obtain the current flow. The duty cycle 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100% were tested on the motor and fan. Motor and fan were run for every duty cycle until they achieve steady state condition before the data were taken. The experiment results are represented in line graphs as shown in Figure 11 to 16.

Figure 11 shows the motor speed (rpm) versus PWM duty cycle based on the panel and HMI reading. The result shows that the motor started to rotate at 40% of the duty cycle. During that time, the speed is recorded at 23.95 rpm for the panel reading and 30 rpm for the HMI reading. When the motor is rotated at 100% of the duty cycle, the recorded motor speed is 134 rpm for the panel reading and 120 rpm for HMI reading. The percentage different between panel and HMI reading is around 22.43% during 40% of duty cycle and 11.02% for the 100% of duty cycle as shown in Figure 12. Overall, percentage difference for the motor is around 1 to 30%.

On the other hand, the fan is started to rotate at the 10% of duty cycle with 2946 rpm based on panel reading and 3015 rpm from HMI reading. When the rotation is at 100% of duty cycle, the fan is recorded to rotate at 3139 rpm for panel and 3225 for HMI reading as shown in Figure 14. The percentage difference between panel and HMI reading for fan speed is shown in Figure 15. It was recorded that the percentage difference of fan speed is around 1 to 3%.

In general, the percentage difference of duty cycle to rotate the motor and fan can be observed due to different range of speed needed based on equipment specification. At the same time, the different readings between panel and HMI reading may occurred due to the errors in the programming equations.

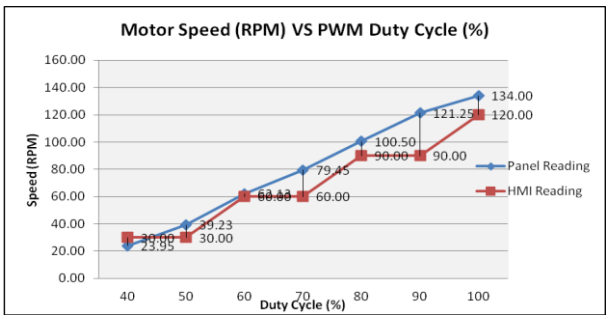

Figure 11: Motor speed (RPM) Versus PWM duty cycle

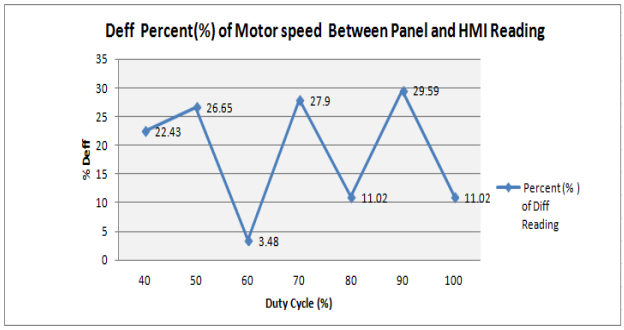

Figure 12: Difference percentage of motor speed between control panel and HMI

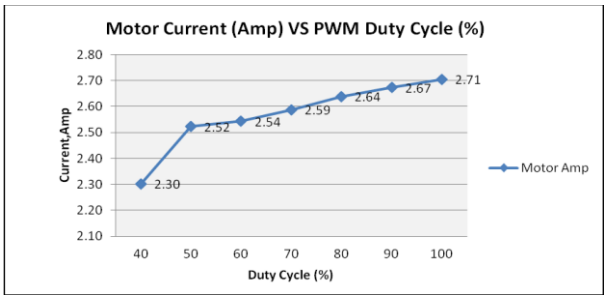

Figure 13: Motor current (amp) versus duty cycle

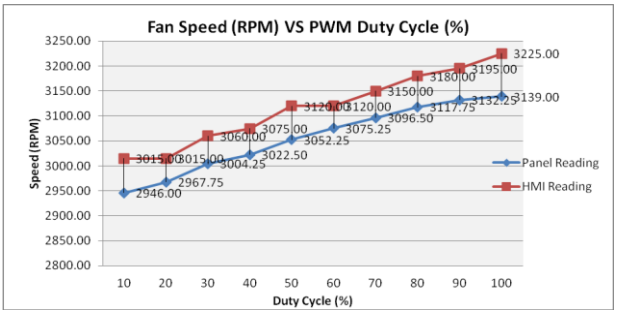

Figure 14: Fan Speed (RPM) versus PWM duty cycle

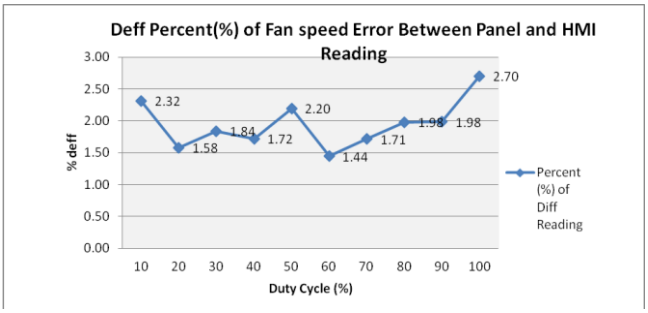

Figure 15: Different percentage of fan speed between control panel and HMI

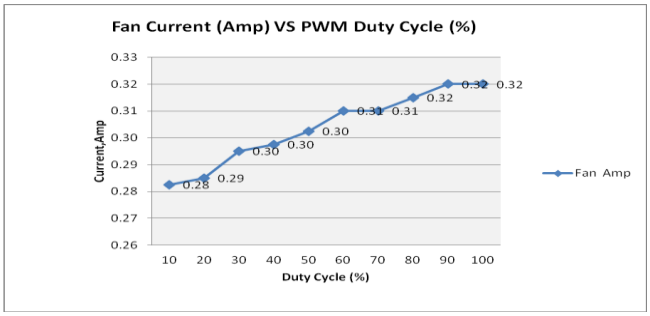

Figure 16: Fan current (amp) versus duty cycle

Lastly, Figure 13 and 16 shows the motor and fan current versus duty cycle. Both graph shows the linearity of the current flow curve to all duty cycles. The current flow consumption for motor and fan required to start the rotation are 2.30 amp and 0.28 amp respectively. The maximum current consumptions for the motor and fan when achieved 100% of the duty cycle are 2.71 amp and 0.32 amp. Speed (rpm) and current flow (amp) tends to be constant when the duty cycle is close to 100%. Based on the current consumption, the selected power supplies for the design is considered enough to support the overall dryer operation. The graphs also proved that PWM speed control worked based on the power supplied to the system via current flow (amp). When the current flow increases the speed of the dryer motor and fan also will increase.

4 Conclusion

In this research, a control system for the *keropok keping* drying machine was successfully developed. Programmable Logic Controller (OMRON) was utilized as a main controller and programming using ladder logic language. The inputs signal can be specified by the user to the controller through the control panel (CP) or human machine interface (HMI). Based on the signal, PLC will make motor, fan and all indicators to work correspondingly. Pulse-width Modulation (PWM) motor speed control was attached for both of motor and fan to control the speed. There are two types of sensors installed into the system which are speed and temperature sensor. The sensors were used to measure the speed, temperature and humidity of the machine during data acquisition (DAQ). A testing was conducted to the system in order to know the relationship between the duty cycle (%) and current flow (amp) to the motor and fan speed (rpm). The percentage difference readings between the control panel and HMI were also measured in order to validate both of the data readings. However some improvement can be taken as further work. The recommendations and suggestions for the improvement can be listed as follows;

a) The Human Machine Interface (HMI) is does not have a special function to control the speed of motor and fan. The system will be better if the function is added into the system software.
b) The wiring is too complicated and the best way is to simplify the components wiring connection.
c) The developed system still has differences readings between control panel and HMI, Some modification needs to be done to the microcontroller C programming language to ensure that the HMI reading will be more reliable.
d) Temperature reading of the dryer machine is still not covered in the testing due to the panel and HMI have not been assembled yet to the actual machine. The effect of the temperature and humidity to the motor and fan speed is another important parameter that needs to be measured in order to know the effectiveness of the dryer.

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