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Automation of Packaging and Material Handling Using Programmable Logic Controller

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Abstract**—*****This paper presents an automation of packaging and material handling using a programmable logic controller. The idea is to automate the process of placing the materials inside a box, detecting good and bad items in terms of weight, and sealing using a packaging tape. The purpose of the study is to replace the manual system being used in the industry, compare the time, and manpower requirement for both the existing system with the proposed automated system. The Mitsubishi FX series programmable logic controller is used to mechanize the system. Sensors such as proximity and load sensor are used to provide the input to the system. The motors, pneumatics, and also the solenoids serve as the output. The researchers used a ladder diagram as a software that will control then the whole system between its input and output components. An experimental prototype is produced to fully automate the system. The experimentation is done through different trials and the rate of travel time is measured thru averaging. It is found out that the system decreases time and manpower requirements for every station as compared with traditional manual system. A reduction of 50% to 75% was observed in terms of time allotment for filling, weighing, and sealing stations. About 90% of full automation without human is specified also in the system. The paper ends with the recommendation of integrating the experimental prototype with the human machine interface or HMI, and feedback mechanisms for the rejected items using artificial intelligence techniques and methods.***

Keywords**—Packaging, Programmable Logic Controller, Material Handling, Load, Sensor**

I. Introduction

Nowadays, automation in the industry becomes the global trend in manufacturing and with the success of the Japanese and European industries in terms of production; more and more companies are switching to automation. Automation is certainly the watchword as today's manufacturers face razor-thin profit margins, Just-In-Time (JIT) manufacturing and the ISO-9002 quality standards. Companies must automate in order to deliver what today's customer is demanding when he wants it and at the price he wants to pay [1]. The boom in manufacturing is led by the new technologies available today as well as low wages, customization, mass production, flexibility, & most importantly, the information [2]. A study on computer aided design (CAD) makes it possible to transmit designs directly to machines that will follow them perfectly. It provides the classical advantages of automation: time and accuracy. Standards for CAD transmissions have been developed such as IGES and STEP. Another study in automation is supported by the new technology hierarchy which is a concept of utilizing a chip on top of a part to be processed. The chip acts as a negotiator for the part communicating with the machines in behalf of the part. It eventually finds a suitable machine to process the part. The main & full purpose of this paper is to design an automated packaging and material handling system. Another purpose is also to help companies planning to switch from traditional product packaging into a more productive and automated packaging system in the assembly line using programmable logic controller. In particular, the following objectives are formulated: (a) to identify the technology that will automate the packaging and material handling, (b) to design a ladder diagram that will automate the system, and (c) to create an experimental prototype that will simulate the automated system. This research is useful as the controls of the machine for a specific job, or a task are processed by the computers. The computer can be programmed depending on the operator (human) decision to perform automatic or not. It can also be beneficial for the future related researches in conducting advance research on industrial automation using programmable logic controllers or the artificial intelligence methods. The company shall benefit with the safe operating system, more efficient factory, faster response time, and few workers also on the actual production line [3]. This paper is focused on automation of packaging and material handling system. Electro-pneumatic and motor control is used for the entire process. The control for the hardware is to be process by the programmable logic controller via the computer. It includes a ladder diagram for programmable logic controller and an actual prototype for the experimentation. The whole system executes the following processes: automation using the programmable logic controller or called as PLC, filling, and packaging. This paper is organized as it follows: Section II briefly presents the programmable logic controller (PLC) and the methodology used in this research paper. Section III is devoted to the experimental results, which are carried out in order to verify the effectiveness of the proposed method by means of the PLC prototype. Conclusion ends the paper at section IV.

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II. Methodology

Fig. 1. illustrates the process of material handling and packaging system, which shall be automated using the programmable logic controller. This is a step by step process on which corresponds to the input and output peripherals that are needed in programming the ladder diagram. Included in the automation is the placement of box, filling of materials, transferring, checking, and sealing of the final product, or item. The overall design is implemented using an experimental prototype.

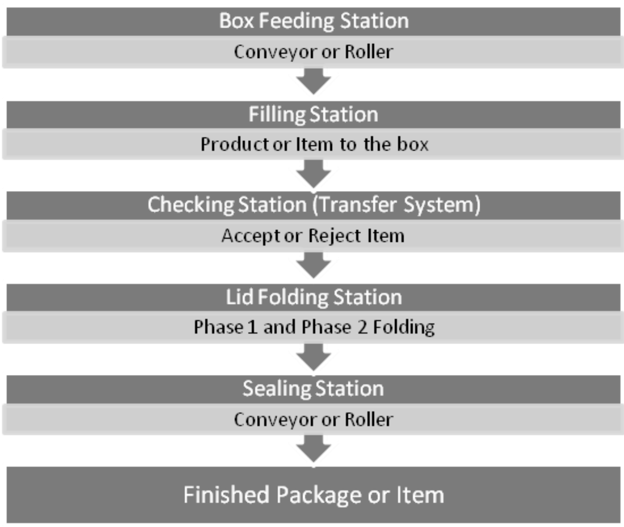

Fig. 1. Flow diagram structure of the automated system.

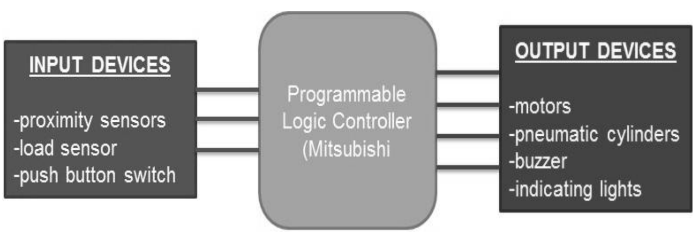

Fig. 2. Conceptual framework for automation using PLC.

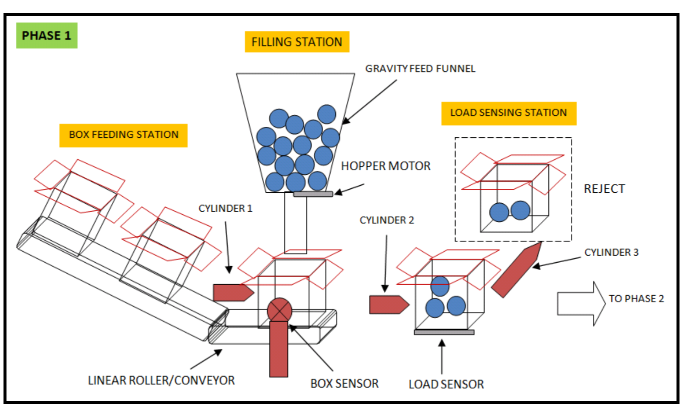

Fig. 3. Design project flow for box feeding, filling, and checking stations.

Fig. 2. shows the general PLC block diagram used by the researchers to implement the automation of the system. From the manual operation, a programmable logic controller is used to convert the system into an automated process. Input components such as sensors and switches are used to indicate the condition corresponding to the hardware flow diagram of the PLC project design. The programmable logic controller interfaced the system and provided the ladder diagram for the design. Output components such as motors and pneumatic cylinders are used to indicate the desired objective of the system. Also, Fig. 3. shows the first phase of the system. As shown, it consists of three stations namely box feeding, the filling, and checking stations. The 2”x2”x2” card-board box is used as the object to be transported. The researchers used a small marble with the same weight to act as a sample material for experimental testing the prototype.

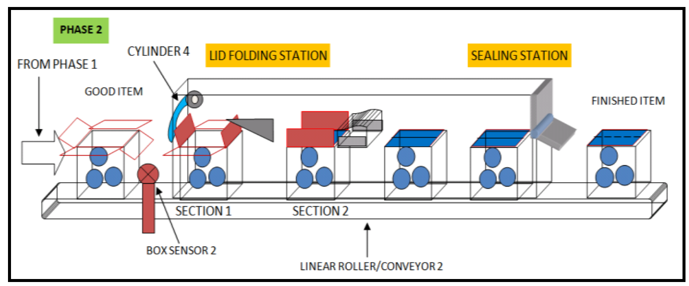

Fig. 4. Design project flow for lid folding and sealing stations.

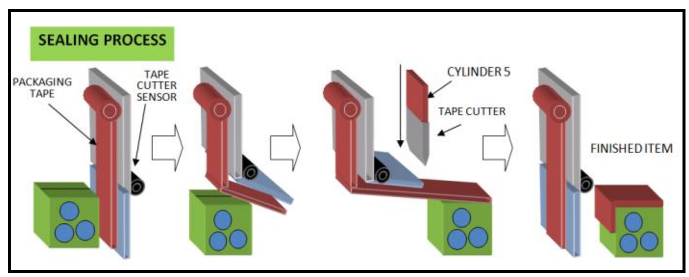

Fig. 5. Sealing process station.

Fig. 4. shows the second phase of the design project. It is composed of two stations namely lid folding and sealing station. Fig. 5. illustrates the detailed automated process for the packaging station. A 1-inch width packaging tape is used to seal the boxes in a single linear direction. A proximity sensor is used to detect the length of the tape that will seal the boxes. A tape cutter made of stainless steel is also used in this station. Below is the discussion of whole operation:

1. When the start button is pressed, box shall be push under the hopper by cylinder 1.
2. Box sensor 1 is provided as to sense the presence of box under the hopper. When a box is detected, hopper motor runs, thus; dropping marbles to the box (box is stationary).
3. A counting sensor is provided as to monitor the correct number of marbles being drop to the box.
4. After the desired numbers of balls is dropped, a load sensor activates as to determine if the loaded box is

overload, under load, or exact load. Good items are pushed to the next station, and phase by cylinder 2, while the under load box and the over load is pushed away from the line by cylinder 3, which is to be checked manually.

5. Having a good item box or load triggers the conveyor 2, to conduct or start its operation. The approaching box is monitored by the box sensor 2.

6. When a box is sensed by box sensor 2, it shall activate

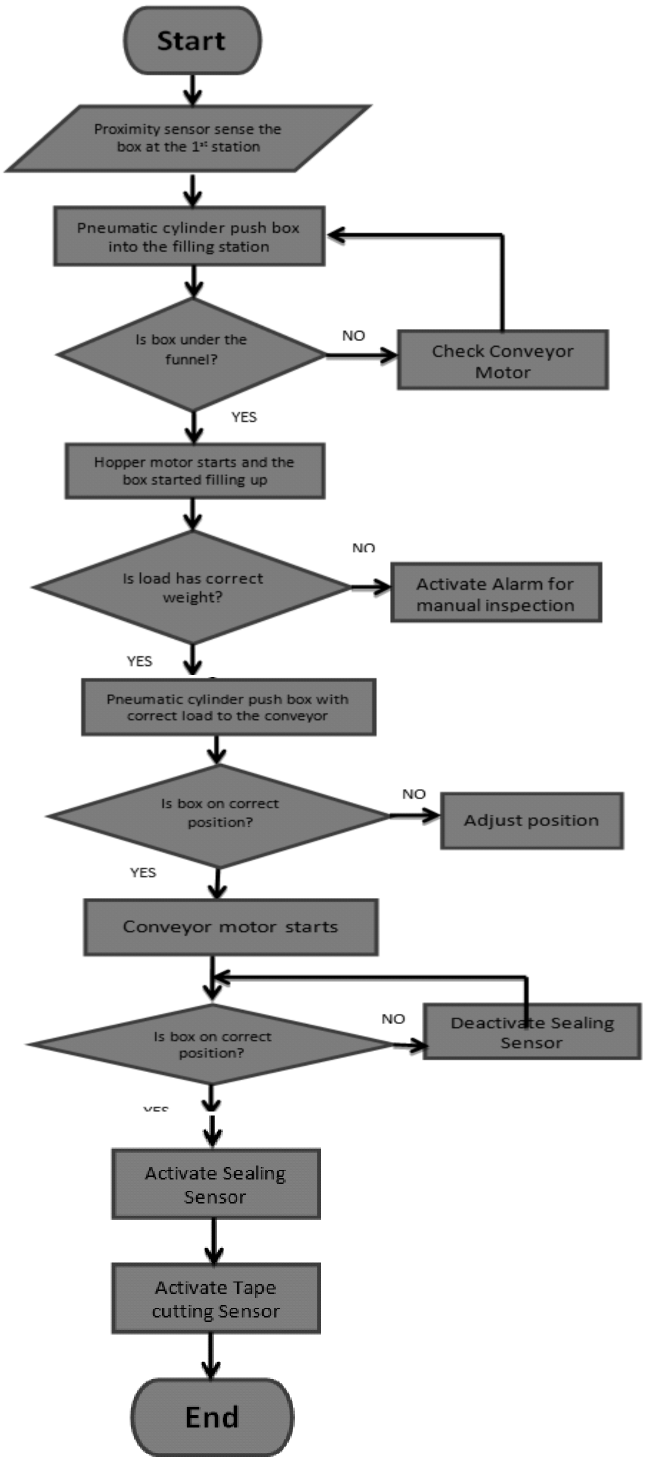

Fig. 6. Software process flowchart.

cylinder 4, and folding the lid of the first section of the side of the box.

7. The second lid and section is folded, as the box moved on the specialized lid folding the obstacle, or as the box makes progress on the conveyor.

8. Having a partially closed box, and a continuous running conveyor, it passes to the sealing station which finishes the packaging process. At this station, a packaging tape, and a cutter is positioned on a flip type window as to allow the incoming box to pass beneath it.

9. The tape cutter sensor shall be triggered, if the flip type window is moved from upward to downward position. This shall activate and turned the tape cutter to move downward via cylinder 5, and cut the tape.

10. Having finished the required task, the system shall point out if another process is to be commenced as invoke by the operator.

11. The finished item shall be collected at the end of the line by the on-duty personnel.

III. Experimental Results

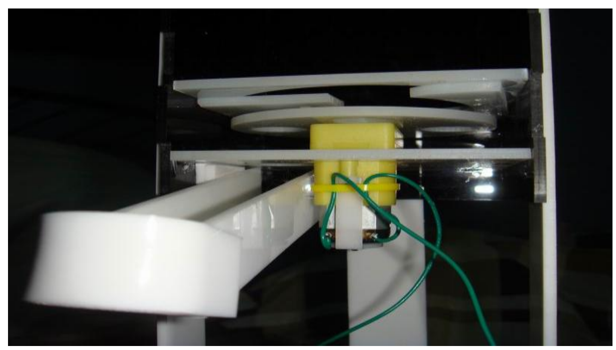

Fig. 7. Gravity feed funnel with hopper motor.

Fig. 8. Experimental prototype.

The researchers tested the prototype timing and signals. The sensors and switches are also tested to ensure that everything is functioning properly as it is programmed. In addition, the travel times of the sample specimens are also added as a parameter, in order to obtain the rate of travel on a conveyor belt as the tables shown. Based on the experimental results and recorded data, five trials are done to measure the amount of time for each sensor to activate. It can be analyze that the load sensor worked only 60 percent of its function. It is observed that during weighing, the sensor experienced difficulty reading.

Table 1. Sensor experimental results.

Trials	Counter Sensor	Load sensor	Proximity sensor	Time (seconds)
1	on	on	on	4.2
2	on	off	off	1.3
3	on	off	on	2.3
4	on	on	on	4.5
5	on	on	on	4.6
Rate (%)	100	60	80	

Table 2. Rate of travel for phase 1 experimentations.

Trial	Time (seconds)	Rate $=\frac{length}{time}$ (meters/seconds)
1	7.3	0.0534
2	7.2	0.0541
3	7.1	0.0549
4	7.3	0.0534
5	7.2	0.0541
Average	7.22	0.0540

Table 3. Rate of travel for phase 2 experimentations.

Trial	Time (seconds)	Rate $=\frac{length}{time}$ (meters/seconds)
1	12.5	0.0406
2	12.6	0.0403
3	12.7	0.0400
4	12.5	0.0407
5	12.7	0.0400
Average	12.6	0.0403

Table 4. Time requirement between manual and automation method.

Tasks	Manually Operated	Proposed Method
Box feeding	2 sec	1 sec
Load filling	7 sec	4 sec
Load checking/inspection	5 sec	2 sec
Lid folding	5 sec	8 sec
Box sealing	8 sec	5 sec

Table 5. Manpower requirement between manual and automation method.

Tasks	Manually Operated	Proposed Method
Box feeding	1	1
Load filling	At least 1	0
Load checking/inspection	1	0
Lid folding	1	0
Box sealing	1	0

A deviation in values happened twice along the operation of phase 1. For this situation, it should be properly calibrated to return a fix value. The proximity and counter sensors worked properly without any failure during the testing process. Also, the travel time of the boxes for the phase 1 and the phase 2 are also gathered. From the tables presented, the values of rate of travel for five trials experience a small deviation from each other. It is then averaged that the total rate of travel for phase 1 is 0.054 m/s. For the phase 2, the average rate of time obtained is 0.0403 m/s. The comparison between time and manpower requirement is also presented. The decrease of at least 50% to 75% in time is obtained for automated than manual system. Also, the system provided a 10% decrease in manpower requirements between the automated and manual operation, which gives the advantage of automation as compared with the manual process.

IV. Conclusion

The automation can be on the same machine level on a production line, or in a whole department where the workers tasks is monitoring, inspection, and maintenance. This paper presented the automation of material handling and packaging in a production line of which this process is done manually in different companies. PLC today are advancing in terms of applicability and capability. The experimental prototype uses a programmable logic controller specifically the Mitsubishi FX 2N 48MR PLC and the electro-mechanical devices. The system works during normal operation and greatly improved the automation processes with the use of the PLC ladder diagram. The wiring and installation procedure are also improved because the PLC input and output devices are assigned with specific addresses, and thus; further simplifies troubleshooting. Cost reduction mainly on the man-power or personnel cost is achieved in this paper. Hence, only one or two personnel are needed for the operation and maintenance with the automated system. After a thorough investigation, the researchers highly recommends extending the other automation processes such as adding input, adding output devices, and also the expansion of the ladder program. The utilization also of the other PLC brands and models may be suggested depending on the need and specifications of different processes. Some PLC is now web-based while some already have the file transfer protocol (FTP) integrated and email applications as well. These controllers can also be used to mechanize the packaging and material handling, giving a hundred percent fully automated system without any human intervention. Also, another recommendation is that some automation process may also be implemented using the FPGA, a DSP chip, a microcontroller, or an ASIC. A wide variety of processor chips are now available in the market, which can be used as an alternative to the PLC for automation process. Integrating the artificial intelligence methods such as artificial neural network, genetic algorithm, swarm intelligence, and fuzzy logic are highly recommended by the researchers.

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