Employment of Automation System in Food Canning of Corn Products

Kant Ananthanathorn*, Nukman Yusoff, Khairul Fikri Tamrin
Department of Engineering Design and Manufacture
University of Malaya, 50603
Kuala Lumpur, Malaysia.
*Email: kant_um@yahoo.com

***Abstract*—Canned foods industry is no longer regarded as a minor player in a global food sector. Canning food is useful to preserve the food quality and taste over a significantly long time period. In this paper, a feasibility study focuses on the employment of an automation system in food canning of corn products specifically at a loading station. A comprehensive data on input and output quantity of defect products was initially collected and studied. Process modeling and PLC programming were developed with aim at reducing such defects by converting the semi-automated mechanism into a fully-automated system. Substantial benefits have been obtained in terms of reduced quantity of defect products, saving in operating cost and reduction of manual staff number.** *(Abstract)*

Keywords-PLC programming; process modeling; automation system; canned food industry

I. INTRODUCTION

Sun Sweet Co. Ltd. was established in 1997 and is one of the leading Thailand companies in food packaging and canning of agricultural products. With over a decade of industrial experience, varieties of food products have been developed to cater the market needs, which include sweet kernel corn, cream style corn and frozen sweet kernel corn. However, the canning process in the manufacturing line majorly depends on semi-manual operation and this could be the main cause of product defects particularly at loading station. Hence, a requirement for a complete automation system within the specific area is deemed crucial to reduce the amount of product defects [1]. A feasibility study is proposed to study the current production line at loading station and suggest possible improvement utilizing design software and PLC programming. A PLC system is installed at one of the loading stations to validate and test the actual performance of the improved loading mechanism.

II. DATA COLLECTION

To identify the sources of product defects, two types of investigations were employed. The first investigation mode was mainly based on observation and in-depth discussion with a production manager who helped in collecting the data. The second mode of investigation involved process modeling [2,3], and production control via PLC programming [4]. Table 1 summarizes the findings and shows the percentage of defects in three separate months.

TABLE I. QUANTITY OF PRODUCT DEFECTS IN THE PRODUCTION LINE

Parameter	July 2011	Dec 2011	Jan 2012
	Quantity of cans		
Input	531,804	7,176,444	5,476,461
Output	526,451	7,148,775	5,446,538
Total defect	3,813	27,842	20,639
% defect	0.72	0.39	0.38

The findings reveal that the amount of defects within the products over a period of six months is not consistent. This is attributed to the nature of production line which relies on semi-automated operation and directly linked to humanly-based errors. Based on Table 1, the specific origins of product defects are categorically defined in Table 2.

Table 2 suggests that the sources of defects are due to machine and process errors as well requirement of operators to work in a semi-automated manufacturing system. In particular, manual operation of seamer contributed as the biggest defect although this can be mitigated through proper staff working hours and manpower management [5]. However, the study focuses in improving the loading system unit.

TABLE II. ORIGINS OF PRODUCT DEFECTS BASED ON TABLE 1

Source of defect	July 2011	Dec 2011	Jan 2012
	Quantity of cans		
Filler	7	358	351
Loader	57	491	375
Deformation of iron case as a result of manual handling	35	862	372
Product fell off the conveyor line	51	175	242
Manual operation of the seamer	186	1333	2013
Problem of head tool	52	979	494

III. PROCESS MODELING

The production line is semi-automated and further supported by two additional workers on each loading point. Altogether, there are 18 processes involved. Fig. 1-3 illustrates the production flow process charts, right from receiving the raw materials through the cleaning and sterilization and finally the loading processes.

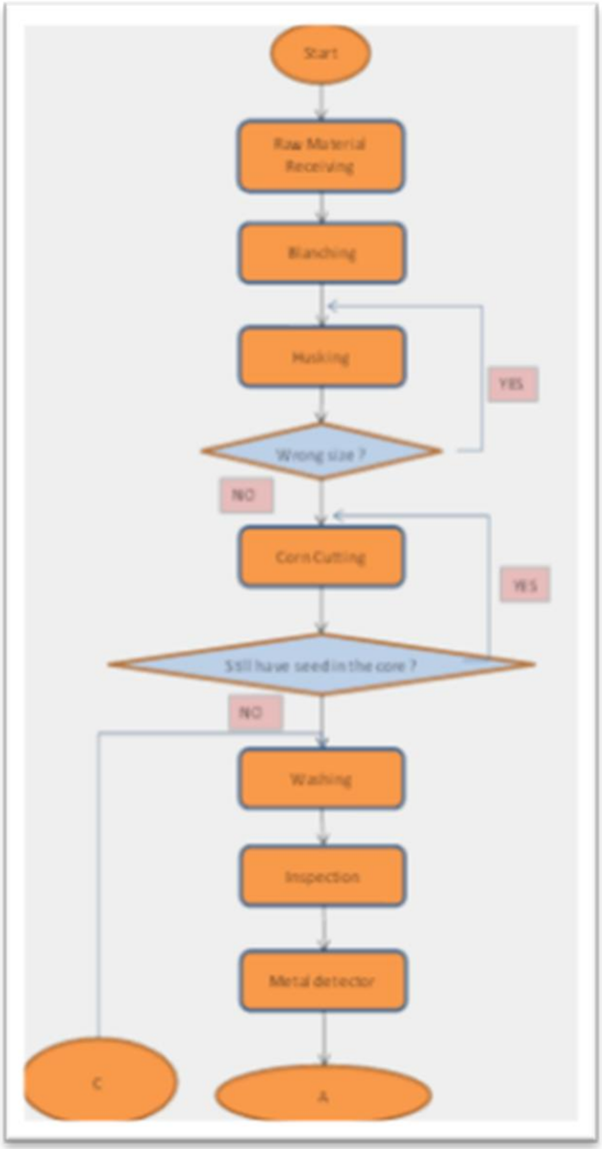

Figure 1. Process flowchart

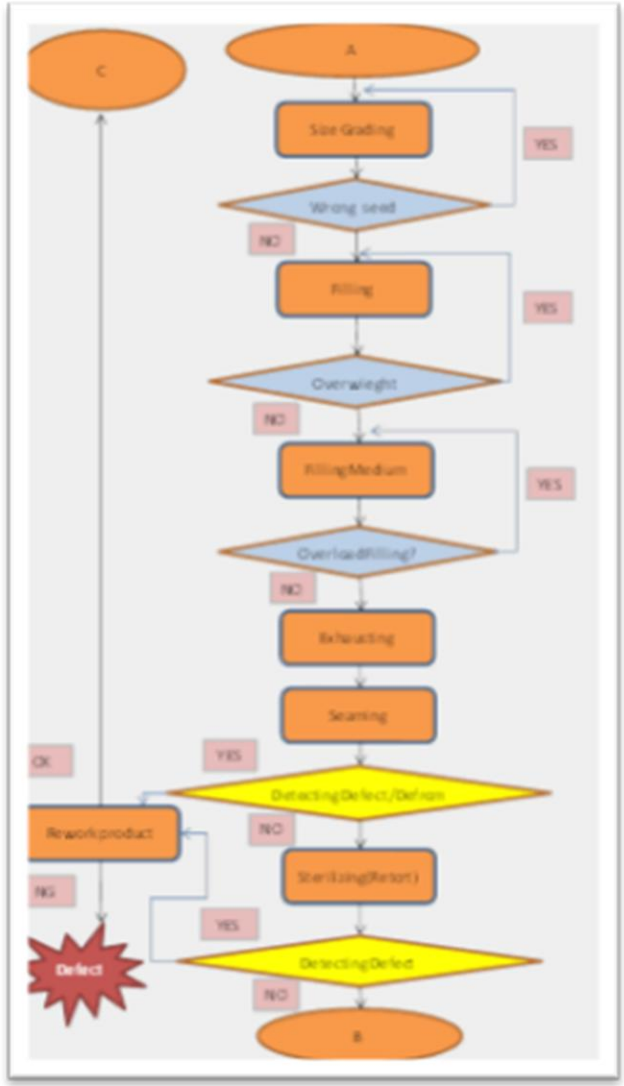

Figure 2. Process flowchart (continued)

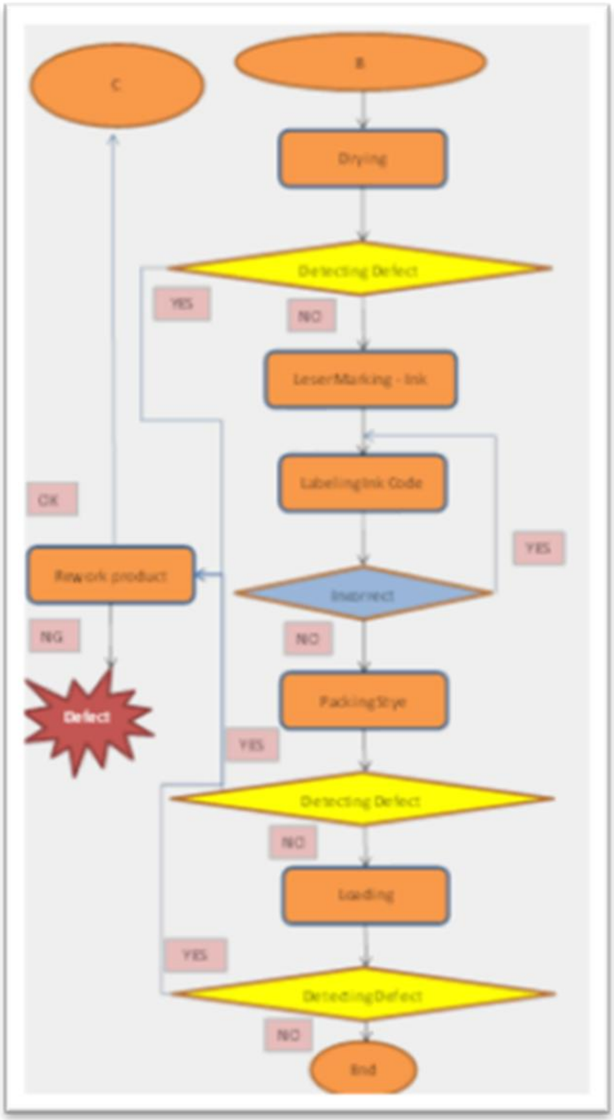

Figure 3. Process flowchart (continued)

IV. Evaluation of the Mechanism at Loading Station

Each loading point typically requires two operators working as a team as shown in Fig. 4. The first operator is stationed in front of the machine, responsible in taking the iron case out of the conveyor. Meanwhile, the task of the second operator is to manually push all the iron cases into a bigger container and finally carry the container to a designated space. This is considered as one work cycle. It should be noted that manual pushing of the case resulted in some damages on the products as they were deformed due to pushing mechanism. The pushing force and its handling rely on the operator, which account for the previously mentioned defect. In total, 560 cans can be stacked into the case (8 levels x 70 cans).

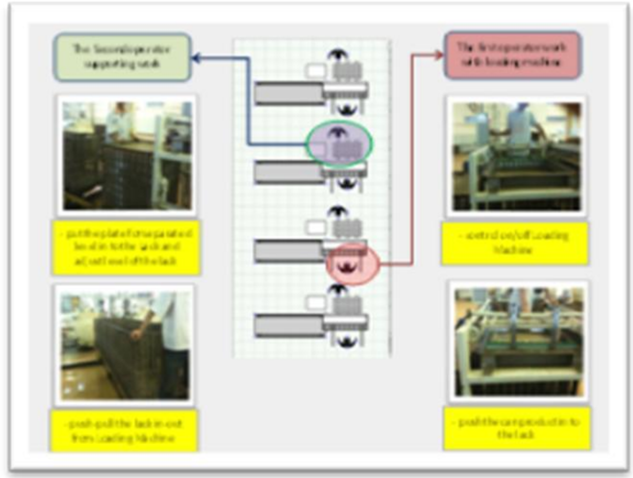

Figure 4. Simultaneous machine and manual operations at loading station.

In addition, the time taken to complete one work cycle varies between operators. Generally, lesser time is required during the morning session in comparison to the evening session due to fatigue and defocused attention to details over long working hours. Table 3 compiles the average time taken for 80 data samples collected within 60 working days. There is huge completion time variation between the first and the second operator by about 30 seconds. This means that the second operator would become idle for that such amount of time. This finding supports the need to install an electro-pneumatic system that can be controlled via a PLC program.

V. PLC Concept Design

It has been considered that a PLC programming and installation would be useful at reducing the defects within the products. The advantages of PLC solutions in the current system include:

a. A single PLC device is flexible enough to control and administer several machines
b. Identification of errors and their origins can be easily spotted using the PLC. The correction is digitally done and undoubtedly cost effective.
c. It proves to be beneficial in system optimization by reducing the amount of manual operations.

In general, the PLC program has been designed as follows (Fig. 5):

a. A proximity sensor works to count the number of cans on the feeding conveyor. The set amount is 14 cans
b. A signal from the sensor is sent to the cylinder and this would turn stop the conveyor from moving.
c. On receiving another signal from the proximity sensor, a pair of cylinders would push the cans into the iron case.
d. A snapping mechanism on the piston would ensure that all cans are successfully moved into the iron case.
e. The cycle is then repeated for the next set of cans.

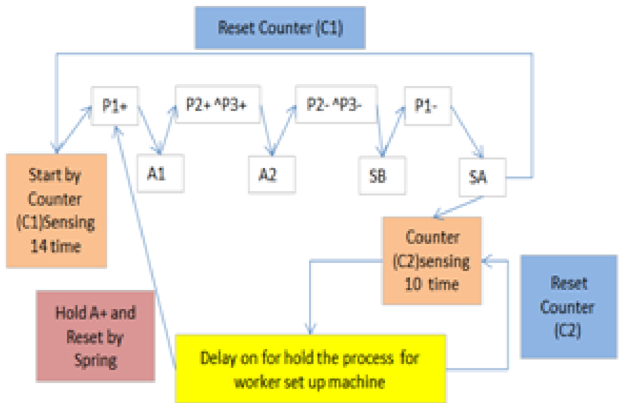

Figure 5. Signal flow diagram in a pneumatic control design.

Fig. 5 shows the overview of the sequential steps employed in a pneumatic control design. It resembles the similar tasks performed by the operators at loading station.

Fig. 6-8 demonstrate the result of circuit control design and electronic signal movement which have been configured to work in synchronization with the pneumatic control (Fig. 5). Then, the pneumatic circuit control was converted to ladder diagram language. The PLC input and output unit, and PLC block diagram shown in Fig. 9 and Fig. 10, respectively. This allows much comprehensive understanding of the logic control and prevents unexpected errors. Finally, the PLC was installed into the loading machine for testing and validation and illustratively shown in Fig. 11.

VI. RESULTS AND DISCUSSION

Table 4 compares the outcome before and after PLC installation into the loading machine. Based on Table 4, the installation of PLC program proved to be successful. The percentage reduction in defect remains the same irrespective of input quantity especially for December 2011 and January 2012. This further suggests that this could be the maximum defect reduction that can be achieved by an automated system. Moreover, the number of total operators at loading station was reduced from eight to four staffs. In addition, the operating cost at loading machine was saved by about 50%. It has been found that:

a. The overall time taken to process the input relied on pneumatic motion and plunger speed.
b. Solid-state PLC has high speed motion on the production line.
c. Segmentation in PLC programming proved important to reduce inefficiency since actuators respond speed and performance vary between manufacturers.

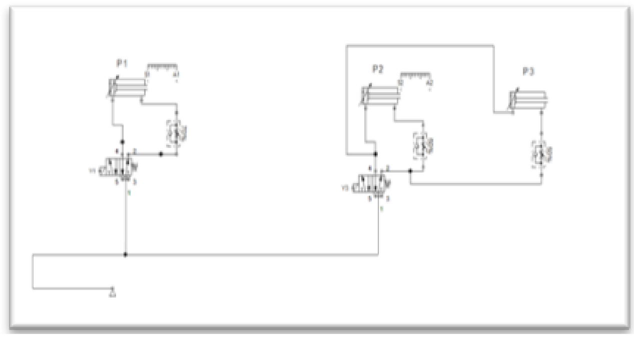

Figure 6. Pneumatic circuit control simulation.

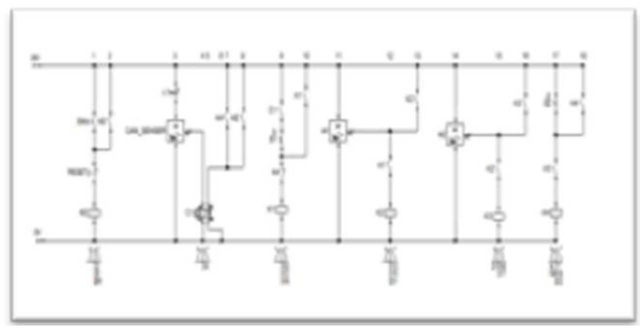

Figure 7. Pneumatic circuit control simulation (continued).

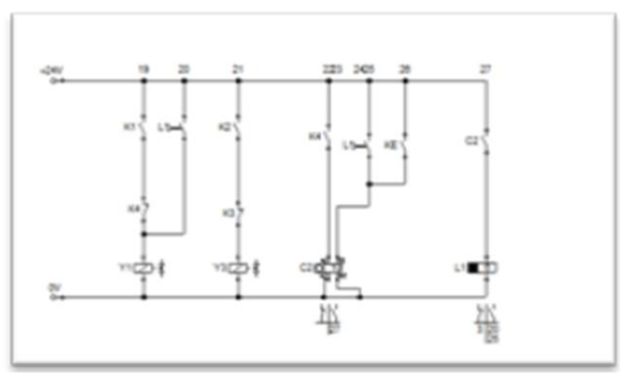

Figure 8. Pneumatic circuit control simulation (continued).

Port	Position	Description
IN CH00 (I)	00	Froximity CAN_SENSER(START) SC
	01	Limit Switch S1
	02	Froximity Sensor A1
	03	Limit Switch S2
	04	Froximity Sensor A2
	05	Emergency EM
	06	Reset
OUT CH10 (Q)	00	Solenoid Valve (reset by spring)Y1
	01	Solenoid Valve (reset by spring)Y3

Figure 9. PLC input and output unit.

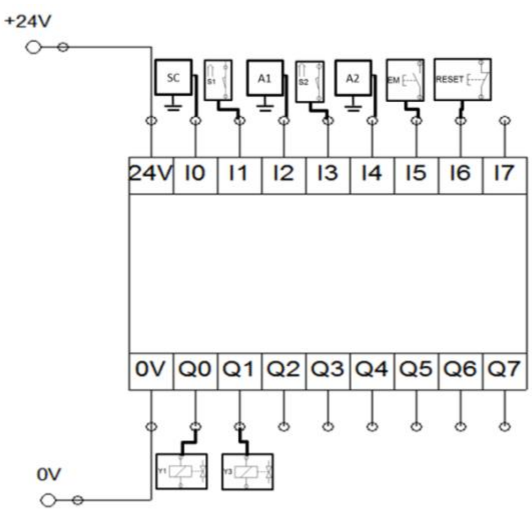

Figure 10. PLC block diagram.

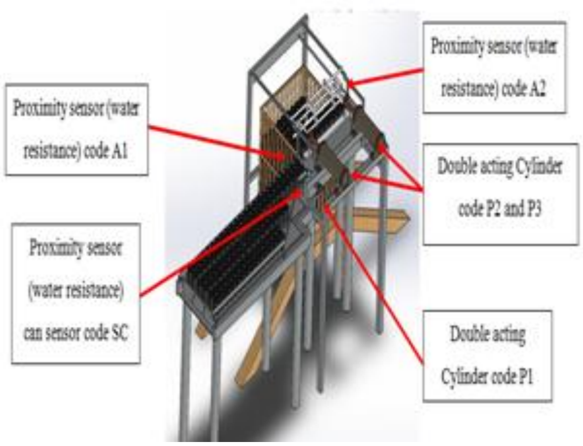

Figure 11. PLC block diagram.

TABLE III. COMPARISON OF OUTPUTS BEFORE AND AFTER THE INTEGRATION OF THE PLC DEVICE.

Parameter	July 2011	Dec 2011	Jan 2012
	Quantity of cans		
Input	531,804	7,176,444	5,476,461
Output (before improvement)	526,451	7,148,775	5,446,538
Output (after improvement)	526,508	7,149,266	5,446,913
Percentage of defect reduction (%)	0.011	0.007	0.007

VII. CONCLUSIONS

Based on the feasibility study, successful implementation of the PLC system at loading station has resulted in reduction of staffs from eight to four, saving in operating cost at loading station by about 50% and an average reduction in defects by 0.0083% over three separate months. However, the installation of a fully-automated system on the shop floor to significantly reduce the quantity of defects at much higher input requires continuous validation and testing works.

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